

Project AIR FORCE

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# TRANSFER PRICING FOR AIR FORCE DEPOT-LEVEL REPARABLES

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*Laura H. Baldwin*  
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*MR-808-AF*

*Prepared for the  
United States Air Force*

**RAND**

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## **PREFACE**

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This report examines the incentives created by working capital fund prices for depot-level reparable (DLRs), as implemented by the Air Force, and discusses the problems that may result from these incentives. These problems affect the Air Force's ability to efficiently meet its support goals. The report then recommends changes in the approach to setting prices that should improve the Air Force's ability to meet its goals efficiently.

The pricing policy for DLRs is an evolving topic within the Air Force and, more broadly, within the Department of Defense. Because of the limited Air Force historical experience and data on the effects of prices on behavior, the issues raised and recommendations found in this report are based upon both the extensive economics and accounting literatures on transfer prices and discussions with Air Force military and civilian personnel at bases, depots, and major command headquarters. The authors' intentions are to use insights from these literatures and discussions to shed light on behavioral issues associated with different pricing strategies for DLRs and to present policy options the Air Force may use to shape its pricing policy. The authors recognize that the recommendations set forth here are not consistent with current DoD and Air Force policy and do not represent the official DoD or Air Force view on prices.

In FY 1998, after the conclusion of this research, the Air Force combined three organizations within the working capital fund to create the Materiel Support Division. This organizational change was accompanied by changes to the structure of DLR prices. Overhead and other non-transaction-related working capital fund

costs are now allocated to the prices of reparable components on a different basis than before.

Only one change to the structure of DLR prices addresses the concerns and policy recommendations discussed in this report. The new structure of DLR prices ties recovery of the cost of replacement items for a particular type of reparable component to the price of only that component. (Previously, replacement costs for each type of component were recovered by spreading them across prices for all components.) For those components whose state of repair cannot be affected by customers, this change should increase customer incentives to take actions that are in the best interest of the Air Force. However, with this exception, the concerns expressed in this report about the adverse effects of the structure of DLR prices on customer behavior remain largely unchanged.

This research was conducted in the Resource Management and System Acquisition Program of RAND's Project AIR FORCE. It was sponsored by the DCS/Logistics, Headquarters USAF. It should be of interest to logisticians and financial management personnel in all of the military departments and the Office of the Secretary of Defense, especially those concerned with the Services' working capital funds and the pricing of their goods and services.

## **PROJECT AIR FORCE**

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## SUMMARY

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The Air Force implemented stock funding to manage most depot-level reparable (DLRs) in FY 1992. The Air Force Working Capital Fund charges customers—wings and higher-level organizations in major commands and repair activities in air logistics centers—for their purchases of serviceable DLRs, pays customers for the return of items needing repair or replacement, and purchases depot-level repair and replacements. The introduction of stock funding for DLRs gave customer commands responsibility for obtaining budgets to purchase DLR repairs and replacements. These budgets were formerly the responsibility of the Air Force Materiel Command, and DLRs were supplied to customers free of charge.

This market-like system is intended to provide incentives for making cost-effective repair decisions at the local level. The establishment of transfer prices for DLRs has increased customer awareness of support system costs, and customers have increased utilization of local repair options to economize on their operations and maintenance funds. However, the influence of DLR prices extends beyond local execution decisions to long-run strategic decisions made by customer commands and the Air Staff.

DLR prices are structured to recover the costs associated with repairing/replacing DLRs plus the costs of overhead and selected nonrepair services, such as software support. The repair cost portions of prices reflect the average condition of items needing repair rather than the condition of individual items. The costs of overhead and nonrepair services are arbitrarily allocated to prices in a surcharge that is proportional to the acquisition cost of each DLR. Including

these costs in DLR prices rather than recovering them separately causes prices to be higher than the costs incurred through DLR transactions and gives the Air Force and customer commands incorrect information about specific DLR, weapon system, and command-related costs.

Although customers may recognize that DLR prices do not reflect the cost of depot-level repair, these prices are the charges that are debited against their budgets and, hence, are the relevant costs of DLRs to wings and commands. Wings and customer commands save operations and maintenance (O&M) funds that they can use for other purposes by reducing their number of transactions with the working capital fund, as long as the cost they incur to avoid these transactions is less than the sum of the DLR prices they avoid paying. However, the Air Force saves money only when the decrease in variable costs associated with the reduction in depot-level repair is greater than the increase in costs incurred by wings and commands. (The costs included in DLR prices that are not related to the rate of repair are incurred regardless.)

In the longer term, commands may seem to benefit from allocating costly repair resources to wings and purchasing fewer serviceable items from the working capital fund because DLR prices overstate the cost savings from doing so. Indeed, DLR prices provide incentives for customers to resist moving repair away from the customer to the depot.

The absence of a financial penalty for returning items in worse-than-average states of repair provides additional ways for customers to save O&M funds. They save when they can send only severely damaged items (i.e., with above-average repair costs) to the depot level and keep items with below-average repair costs at the local level. Customers also save when they can prolong their use of mechanical items or cannibalize to consolidate failures so that they will have fewer transactions with the working capital fund. However, the Air Force saves money only when the reduction in costs resulting from fewer repairs is greater than the increase in costs resulting from increased repair cost per item. DLR prices will ultimately reflect the higher average repair costs, but higher prices increase customer savings from degrading the condition of items repaired at depot level and thus strengthen customer incentives to do so.

The structure of DLR prices also works against accurately recovering costs from customers. Because costs unrelated to the rate of repair are recovered through the DLR surcharge, accurate recovery depends on accurate forecasts of DLR transactions. When the realization of customer demand for DLRs differs from demand forecasts, these costs are under- or overrecovered.

The structure of DLR prices should be changed to improve the compatibility of customer incentives and overall Air Force support goals and to be robust with respect to changes in those goals. The price system should cause customers to face the costs their decisions impose on the support system. That is, costs should be recovered through a series of charges to the customers responsible for generating those costs. In order of priority, our recommendations are:

- DLR prices should not include a surcharge. Costs unrelated to rate of repair should be recovered from customers, but not through DLR prices.
  - Fixed or sunk costs should be allocated to customer commands through periodic charges according to their source.
  - Prices should be established for customer services that are unrelated to the rate of repair.
- DLR prices should include all costs that vary with the number of transactions (e.g., repair resources, replacement items, Defense Logistics Agency issues and receipts charges, transportation, and pipeline inventory).
  - When customers cannot affect the condition of a returned carcass, the DLR price should equal the average cost of a transaction for the particular DLR and not reflect the condition of the returned carcass.
  - When customers can affect the condition of a returned carcass (e.g., through excess usage, cannibalization, or sorting), the DLR price should reflect the condition of the returned carcass.
  - The price of a DLR in excess supply should be discounted based on the length of time until repair or replacement is necessary.

- Headquarters U.S. Air Force should be the customer for services that may be undervalued by customer commands.
- Pipeline inventory fees should be used to penalize delays and reward reductions in pipeline times at wings and depot repair shops.

If customers were to face the costs they impose on the Air Force, they would recognize the cost advantage of depot-level repair when it exists. Similarly, customers would adversely affect the condition of carcasses only when it is cost-effective from the point of view of the Air Force. Establishing separate charges for nonrepair services would encourage customers to balance their costs against the benefits received and, in the presence of potential competition, will encourage suppliers to provide these services more efficiently. Finally, recovering fixed costs and costs of nonrepair services separately from DLR prices would better align working capital fund costs and revenues.

When changes in support strategies result from changes in costs, DLR prices will reflect the cost changes and reinforce the support strategy changes. For example, reduced commercial transportation times and costs may cause the Air Force to centralize the repair of broad classes of items at depot level. This reduction in the cost of depot-level repair would be reflected in DLR prices. However, if wing and higher-level organization support considerations differ (because the higher-level organizations have broader scopes of resource responsibilities), prices should be adjusted to provide wings with the correct incentives. That is, prices should be structured so that customers view the Air Force's preferred source of repair as the least expensive source of repair.

The efficacy of our pricing recommendations is limited in three ways. First, depot repair costs currently cannot be measured accurately. Without improved tools for cost analysis (such as activity-based costing) and a reduction in the time lag between estimating and realizing costs, the match between DLR prices and expected marginal costs will be imperfect; therefore, the decisions based on these prices may not always be best for the Air Force. Second, the financial management system is not currently able to implement all that is required to fully adopt the pricing strategy. However, eliminating the

DLR surcharge—recovering most of the costs through separate charges to commands and recovering the remaining costs through appropriate assignment to DLR prices—would yield the single largest improvement in customer incentives and is feasible given the current financial management system. Finally, restrictions on competition for repair among depots and between depots and commercial firms limit the incentives of depot repair shops to reduce their costs and limit customer opportunities to seek out lower cost repair alternatives.

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## ACRONYMS

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ACC	Air Combat Command
AETC	Air Education and Training Command
AFB	Air Force Base
AFMC	Air Force Materiel Command
ALC	Air logistics center
BOM	Bill of materials
CND	Cannot duplicate
COD	Cost of Operations Division
CONUS	Continental United States
DBOF	Defense Business Operations Fund
DLA	Defense Logistics Agency
DLE	Direct labor efficiency
DLR	Depot-level reparable
DMAG	Depot Maintenance Activity Group
DMBA	Depot Maintenance Business Area
DMRD	Defense Management Report Decision
DPAH	Direct product actual hours
DoD	Department of Defense
DRC	Depot repair cost
EP	Exchange price
FAC	Forecast acquisition cost
FY	Fiscal year
G&A	General and Administrative



Hq USAF	Headquarters United States Air Force
LRU	Line-replaceable unit
MDS	Mission/Design/Series
NSN	National stock number
O&M	Operations and Maintenance
O&S	Operating and Support
OSD	Office of the Secretary of Defense
PDM	Programmed Depot Maintenance
RSD	Reparable Support Division
SMAG	Supply Maintenance Activity Group
SMBA	Supply Management Business Area
SRU	Shop-replaceable unit
SSD	System Support Division
TRANSCOM	United States Transportation Command

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**INTRODUCTION**

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Defense Management Report Decision No. 904 (DMRD 904) mandated that the Air Force establish stock funding for managing depot-level reparable (DLRs).<sup>1</sup> Around the same time, the Air Force Stock Fund was made part of the Defense Business Operations Fund (DBOF). In early FY 1997, the DBOF was replaced by four “working capital funds,” one each for the Air Force, Army, Navy, and a defense-wide fund. Within the Air Force Working Capital Fund, DLRs are managed by the Reparable Support Division (RSD) of the Supply Management Activity Group (SMAG), formerly known as the Supply Management Business Area (SMBA).<sup>2</sup> In this market-like management system, inventory held by SMAG is sold to customers: wings and higher-level organizations in major commands and repair activities in air logistics centers (ALCs). Proceeds from the sales—over \$3 billion per year—are then used to pay for depot-level repair services, replacements, and working capital fund operations. Specifically, SMAG transacts with the Depot Maintenance Activity Group (DMAG), formerly known as the Depot Maintenance Business Area (DMBA), for repair of DLRs and with contractors for repairs of other

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<sup>1</sup>*Defense Management Report Decision No. 904*, approved November 11, 1989, also mandated that Air Force consumables be stock funded and that the Army adopt stock funding as well. The Navy adopted stock funding for depot-level reparable in the early and middle 1980s.

<sup>2</sup>The fund for base-level reparable and consumables is the System Support Division (SSD). RSD manages over 162,000 items with projected sales of \$2,998.8 million for FY 1997. SSD manages over 51,000 items with projected sales of \$360.5 million for FY 1997. Source: United States Air Force, *Defense Business Operations Fund: FY 1997 President's Budget*, March 1996.

DLRs and replacement items (see Figure 1). Stock funding was fully implemented for most DLRs in FY 1992.

The Department of Defense (DoD) believes that charging customers according to the costs of the goods and services demanded and giving managers the authority to make trade-off decisions should “control costs, promote efficiencies, and allow sound economic decisions.”<sup>3</sup> From the Air Force point of view (which is both the demander and supplier of support services), this means using DLR prices—known as “transfer prices” in the economics and business literatures—to help achieve support system goals at least cost. How successfully these DoD goals are realized depends first on the extent to which prices influence decisions—that is, whether or not managers have the flexibility and the incentive to make trade-offs among alternatives. If prices *do* influence decisions, prices must be structured to induce decisions that contribute to the goals rather than detract from them.

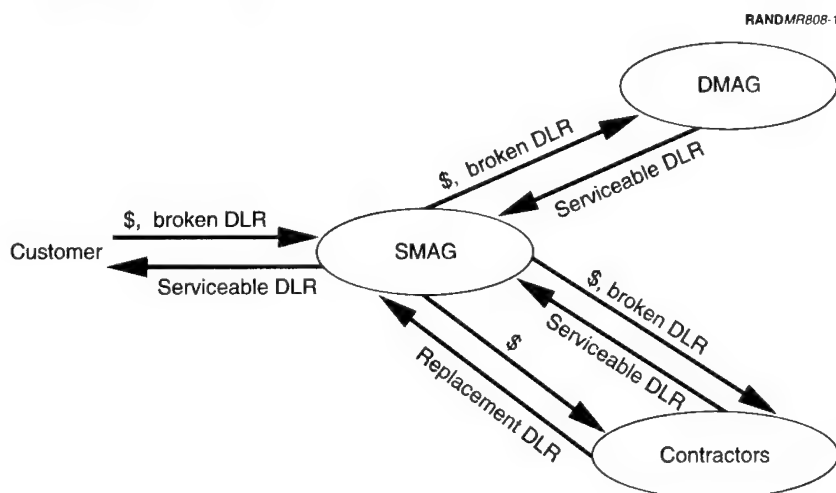


Figure 1—Air Force Working Capital Fund Transactions

<sup>3</sup>OSD (Comptroller), *An Overview of the Defense Business Operations Fund*, n.d., p. 4. See also Undersecretary of Defense (Comptroller), DOD 7000.14-R, p. 50-1-1.

Are prices affecting current decisions? We were unable to identify data that would allow us to quantify how and the extent to which decisions are affected by DLR prices. There is general agreement that customers have responded to the establishment of DLR prices in ways that save the Air Force money. For example, customers are reducing costs by repairing more of the items that they are staffed and equipped to repair locally rather than sending them to the depot.<sup>4</sup> Also, customers are returning more of their unserviceable DLRs for credit when purchasing serviceable ones from the working capital fund, reducing required purchases of replacement items.

However, there is considerable anecdotal evidence that some DLR prices do not induce the decisions that the Air Force would like customers to make. Customers are taking actions to avoid transacting with the working capital fund for some items that the Air Force has determined are best repaired at the depot level. For example, in some cases, customers are able to reduce the number of DLRs exchanged by taking actions that cause unserviceable items to be in extremely poor condition (state of repair) when they reach the depot. Although the number of repairs falls, the total repair cost may increase. Also, customers have incentives to resist moving repair from the local level to the depot level even when the Air Force has determined that depot-level repair is in its best interests.

These problems occur because the current price structure induces customers to avoid purchasing DLRs from the working capital fund. DLR prices do not reflect the costs of providing repair and replacement services nor are they tailored to Air Force support plans for individual items. Instead, current prices are typically much higher than the cost of depot repair, creating cases in which local repair (organic or contractor) is cost-effective for customers but not for the Air Force as a whole. Also, prices do not reflect the varying conditions of the unserviceable DLRs; thus, customers do not see the cost associated with altering the state of repair of items.

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<sup>4</sup>Local repair is less expensive than depot repair in the short run if the wing has already been provided the manpower and equipment to perform the repairs. Sending these items to the depot adds the costs associated with transportation and the longer repair pipeline.

The Air Force has limited the extent of these problems by constraining the ability of customers to respond to incentives created by DLR prices. For example, customers must obtain permission to substitute local sources of repair for depot-level repair. Thus, the Air Force implicitly recognizes that the DLR pricing structure provides incentives that are not always consistent with Air Force goals.

This study examines the support decisions that are influenced by DLR prices and the problems generated by the current DLR price structure, and it recommends changes in the approach to setting prices that should alleviate the problems. Underlying our recommendations is the notion that the support system is changing, and there is considerable uncertainty about its final structure. Our recommendations lead to a price system able to accommodate broad changes in support strategies.

## ORGANIZATION OF THE REPORT

Chapter Two discusses the support decisions affected by DLR prices and repair costs. Chapter Three describes the current DLR price structure. Chapter Four explains how the price structure prevents the Air Force from achieving its goals of controlling costs, promoting efficiencies, and allowing sound economic decisions, and Chapter Five recommends changes that would alter incentives and improve the Air Force's ability to achieve these goals. Chapter Six provides some final remarks on the recommendations and indicates limitations on the gains from their implementation. Appendix A discusses recommendations from the accounting and economics literatures on internal transfer prices. Appendix B provides the mathematics of the pricing recommendations found in Chapter Five.

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**THE ROLE OF DLR PRICES IN DECISIONS**

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When the Air Force first established DLR prices, the prices were expected to influence the day-to-day decisions that wing maintenance personnel make about repairing unserviceable DLRs that they are equipped to repair versus purchasing serviceable ones through the working capital fund (hereafter referred to as the “fund”). However, DLR prices also provide powerful financial incentives for customer commands and depot repair shops. As a result, these prices influence a broad spectrum of decisions affecting DLRs, including decisions made during the planning process.

In this chapter, we examine decisions affecting two classes of DLRs: line-replaceable units (LRUs) and shop-replaceable units (SRUs). LRUs are components that are removed and replaced at the flight line. SRUs are components that are removed and replaced at intermediate or depot level. Not all LRUs and SRUs are reparable, but our concern here is only with those that are.

## **WINGS**

Wings make at least two types of decisions that affect DLRs. Wings choose between purchasing serviceable units through the fund and repairing them locally, whether or not they are authorized to do so.<sup>1</sup> If a wing decides to go through the fund, it must decide when to re-

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<sup>1</sup>A wing can recommend local repair of a DLR to its major command; however, the major command and the Air Force Materiel Command (AFMC) must approve the change in level of repair.

turn the unserviceable unit. Wings can also affect the state of repair of carcasses through consolidation of broken SRUs (cannibalization), extended or reduced use of units before removal from aircraft, or other action.

These decisions are depicted in Figure 2. Repairing a DLR locally or purchasing a serviceable one from the fund is a strategic decision. Local repair requires an allocation of repair resources to the wing (see the discussion of customer commands below). The decision of whether to cannibalize a DLR at the local level (or change the time between removals) depends on the nature of the DLR.

When making these decisions, wings are primarily concerned with achieving their flying program and readiness goals; however, wing commanders may also have secondary goals such as improving quality-of-life programs. Each wing must achieve its goals within the constraints of its assigned manpower, repair equipment, and operations and maintenance (O&M) budgets, all of which are provided by the command. The wing commander does not have the flexibility to trade among these three types of resources.

All else equal, wings have a preference for local organic repair because of the perception that it is more responsive than depot-level

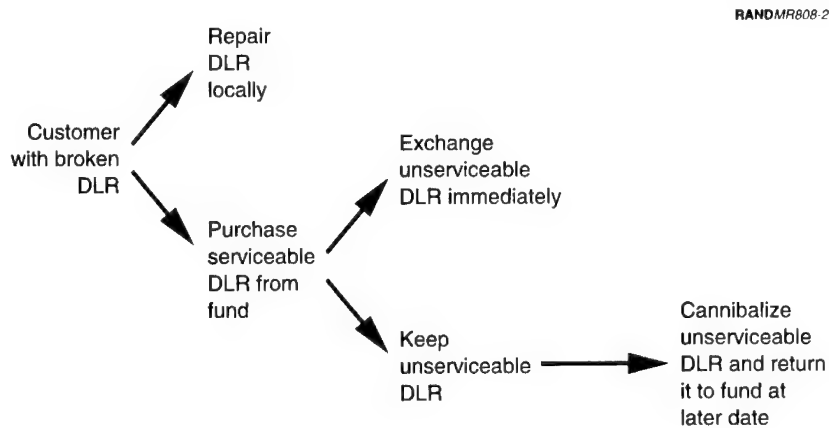


Figure 2—Wing Decision Tree

repair. Trained military repair personnel are highly motivated and can work overtime to achieve flying program and readiness goals, whereas wings believe that DLR budgets cannot accommodate higher-than-expected demands for serviceable units and cannot guarantee that there will be serviceable items in supply when needed. This means that if wing commanders are asked to give up their organic maintenance capabilities in exchange for DLR funds to purchase the items that previously were repaired locally, they will believe themselves worse off because they will no longer have the same flexibility to meet surges in demand.<sup>2</sup> Also, if a wing lacks confidence in the ability of the supply system to provide serviceable units when needed, it will prefer local organic repair even when it has DLR repair funds to meet unanticipated demand. Because local repair resources and DLR funds are not viewed as being perfect substitutes for one another, wing commanders will make decisions that favor local organic repair over depot-level repair to reduce the risk of not achieving their primary goals.

At wings, operational considerations generally dominate budgetary ones. Indeed, given that wings' budgets are tied to DLR prices and expected demands, it is not obvious why wings' actions should be influenced by these prices. However, there are several reasons why DLR prices play a role in wing decisions. First, at least one command, Air Combat Command (ACC), has received smaller budgets for DLRs than it requested and has had to draw funds from other areas to cover DLR expenditures. Wings are aware of this budgetary shortage and feel pressure to find ways to reduce DLR expenditures. More generally, commands set standards for cost per flying hour. All else equal, a wing commander does not wish to appear less fiscally responsible than other wing commanders.<sup>3</sup> Second, with the introduction of prices and budgets, an unexpected increase in removals

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<sup>2</sup>Apparently, for at least some units, it is not uncommon for organic maintenance personnel to work overtime to support the normal pace of operations. If this is true, surge capacity is eroded and the associated incentive to favor organic repair is reduced.

<sup>3</sup>The wing tracks its expenditures on consumables, fuel, and DLRs because these are the primary costs that it can influence. The Sustainment Executive Management Report (SEMR 97) constructed by AF/LGMY indicates that for the B-52 and the F-16, DLR expenditures between FY 1997 and FY 2002 are expected to exceed expenditures for fuel and consumables, and for the C-141, DLR expenditures are expected to be less than fuel but greater than consumables expenses.



for DLRs can prematurely deplete a wing's budget, leading to temporary shortages of serviceables. Third, if a reduction in DLR expenditures results in a surplus of O&M funds at the end of the fiscal year, organic maintenance organizations may receive some of the extra funds to upgrade their facilities.<sup>4</sup>

In the short run, when local repair resources are fixed, wings have incentives to substitute away from depot repair through cannibalization, prolonged use of DLRs, and unauthorized local repair in order to conserve funds for potential surges in demand for items that *must* be sent to the depot for repair. A wing can compare DLR prices and local variable repair costs to determine which types of items yield the greatest savings when it avoids exchanging them through the fund. The wing will then focus on finding ways to substitute away from depot repair for these items.

In the long run, wings can influence command decisions about what types of repair resources to provide (discussed below), wings may gather additional repair capacity at the local level, and resist the removal of repair capacity. When recommending a change in level of repair for a specific DLR to its major command, a wing may use DLR prices to justify the change, comparing the total outlays to the fund with the perceived cost of the organic repair capability.<sup>5</sup>

## CUSTOMER COMMANDS

Major customer commands directly affect the level of repair. Jointly with AFMC, customer commands determine the initial levels of repair for new weapon system components, and commands participate in revisiting level-of-repair decisions for items already in the active inventory. In addition, customer commands *implicitly* affect the level of repair and state of repair of items currently in the inventory through their allocations of military manpower, repair equipment,

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<sup>4</sup>We learned of one Air Education and Training Command (AETC) maintenance shop that late in the fiscal year develops a "buyout" list of things it would like to have. Thus, it is ready to request funds should any become available.

<sup>5</sup>Wings are not provided with a standard methodology to calculate the total cost of performing a repair locally. We have heard that these calculations often include only the cost of materials and labor and do not take into account the cost of equipment depreciation, inventory costs, and so forth.

and O&M funds to the wings each year. For example, the command may not provide sufficient repair manpower or equipment for selected repairs authorized at the local level, thereby increasing the number of these repairs performed at depot level. Alternatively, the command may provide wings with some types of repair equipment and repair manpower that can be used to repair items in addition to the intended ones or to alter the state of repair of items (e.g., screening capability for F-16 avionics provides opportunities for cannibalization).

The goals of a customer command are much like those of its wings. A command is primarily concerned with making sure that its wings achieve their flying programs and meet all readiness goals. However, it must also be concerned with a broader set of issues. For example, ACC must be concerned with the deployment footprints of its wings and squadrons—how much repair equipment and manpower it deploys—because of transportation capacity constraints. The command must also bear the additional costs associated with local repair that wings do not see, such as the opportunity cost of devoting manpower to repair and the cost of deploying extra people and equipment or transporting unserviceables to individual bases rather than centralized repair facilities during deployment.<sup>6</sup> Thus, even though the command tends to reflect the views of its wings and, hence, also tends to prefer local organic repair to depot-level repair, its views of costs may drive it to choose repair outcomes that differ from those desired by its wings.

Unlike its wings, the command can make trade-offs between limited resources for local and depot-level repair (manpower, repair equipment, and O&M funds) for each of its wings during the planning and budgeting process each year. During the execution year, the command can move resources between wings, but the command's total O&M dollars and military manpower are fixed.

DLR prices can play a role in the command's trade-off decisions during the planning process, as do the responsiveness of depot-level repair and deployment considerations. The command sees DLR

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<sup>6</sup>When FedEx or another commercial carrier can transport components back and forth between CONUS and the theater, transportation costs may not differ between installation repair and centralized repair.

prices as the cost of having depot-level repair; thus, DLR prices, weighed against what the command views as the full cost of local repair, indicate the items that yield the largest savings to the command from avoiding transactions with the fund.

In the long run, commands may reverse level-of-repair decisions, devoting scarce manpower resources for those repairs that yield the largest savings in terms of DLR prices and shifting other repairs to the depot level. For example, partly because of high prices for F-16 avionics, ACC has chosen to retain avionics test stands and the associated manpower at its wings for screening even though intermediate-level maintenance for these DLRs has been moved to the depot.<sup>7</sup>

In addition, commands have established new organizations within wings' logistics support squadrons (Gold Flag in ACC and GOLDWAY in AETC) to seek out sources of repair for consumable items and alternative (local) sources of repair for DLRs. Their focus is clearly on reducing costs to the wing (and thus the command).

## DEPOT REPAIR SHOPS

In addition to supplying repair services to the fund, depot repair shops purchase SRUs, some of which are themselves DLRs, from the fund when SRUs are needed to repair LRUs.

Depot repair shops make decisions that affect the cost and speed of depot-level repair. See Figure 3. When repairing unserviceable LRUs, depot repair shops are supposed to exchange broken DLR SRUs (e.g., electronic cards in F-16 avionics boxes) for serviceable replacements through the fund. The fund then transacts with the appropriate shop for repair of the unserviceable SRUs. However, because the two shops are frequently located in the same facility, LRU repair shops can choose to route a job directly to the SRU repair shops, rather than transact with the fund. Bypassing the fund is called "job routing."

One goal of the depot repair shops is to increase the measured efficiency of the repair process, that is, reduce cost and repair time

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<sup>7</sup>See Camm and Shulman (1993).

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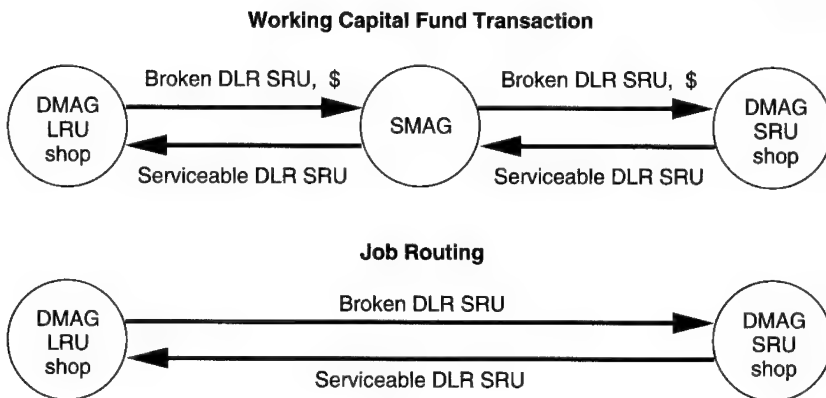


Figure 3—Depot Repair Shop Transactions

without reducing quality. Shops try to improve efficiency because customers will seek to move repair from the depot to the local level if there are cheaper sources of repair or if the supply system is unresponsive to their requests for serviceable items. Clearly, the strength of shop incentives to improve efficiency is positively related to the possibility of competition.

There are several reasons why LRU shops may job route rather than transact with the fund. Through job routing, the LRU repair shop reduces its risk of not being able to get serviceable SRUs in a timely manner. When the LRU shop returns an unserviceable SRU to supply, there is no guarantee that it will receive a serviceable one immediately. If there are no serviceable units in the inventory, supply hands out serviceable units returned from repair based on priority, so the SRU turned in by the shop may go to a different customer after it is repaired, causing the shop to have to wait for a serviceable item. However, when the LRU shop job routes the broken SRU directly to the appropriate repair shop, it is guaranteed to get that SRU back as soon as it is repaired.<sup>8</sup>

<sup>8</sup>However, if supply has the SRU in stock, job routing does not shorten the time that it takes the LRU shop to get a serviceable SRU. From the Air Force's perspective, the in-

If fund prices for SRUs are higher than the amounts the SRU shop charges for repairing them, LRU shops also have a financial incentive to job route. The total cost of repairing a type of LRU in a given year is calculated by adding the cost of the manpower and equipment in the LRU repair shop, the transfer prices paid to the fund for serviceable SRUs, and the portion of the cost of the SRU repair shop that can be attributed to job-routed items. As repair shops lower their operating costs, DLR prices become lower, and depot-level repair looks more favorable when compared with local repair. This improves the repair shop's chances of continuing to be authorized to perform the LRU repair.<sup>9</sup>

## AIR STAFF

The Air Staff makes strategic decisions on the number and types of weapon systems to be supported in the active inventory. Limited budgets mean that estimated operating and support (O&S) costs of the weapon systems are inputs to these decisions, and DLR prices are components of these costs.

For some weapon systems, DLR expenditures are significant proportions of the cost estimates. Table 1 provides estimates from the Air

**Table 1**  
**DLR Costs as a Percentage of O&S Costs**

Aircraft	FY 1996 DLR Costs as a Percentage of O&S Costs
B-1B	29
F-15C	24
C-141B	9
C-130H	5
F-16C	18
E-3B	14

ventory costs of the two transactions should be the same. SMAG's portion of the fund transaction does not add significantly to the flow time.

<sup>9</sup>A third reason to job route is to protect employment in the SRU repair shop. If demand is low for repairs at this shop and if supply has plenty of spare SRUs, transacting with the fund may not generate work for the SRU repair shop, whereas job routing does.

Force's SABLE model of the percentage of several weapon systems' O&S costs attributable to DLR expenditures.<sup>10</sup>

The differences among weapon systems can be attributed partially to the composition of DLRs needing repair and the demand rates of these DLRs. In particular, weapon systems with relatively larger and more sophisticated electronics will have higher percentages of O&S costs attributable to DLRs.

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<sup>10</sup>These are the estimated expenditures by customer commands and do not account for the cost of DLRs used in the repair of non-stock-funded items, such as DLRs replaced during programmed depot maintenance (PDM). We are indebted to our colleague Gary Massey for providing these data.

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**STRUCTURE OF DLR PRICES**

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A sale takes place when maintenance personnel draw a DLR from supply. Depending on the nature of the transaction, customers face three different prices for DLRs: standard price, exchange price, and carcass price. The standard price is paid when the customer purchases a serviceable DLR without turning in an unserviceable one. The exchange price is paid when a customer exchanges an unserviceable DLR for a serviceable one. The carcass price is then paid if the customer fails to return the unserviceable DLR within 60 days of receiving the serviceable unit.<sup>1</sup> The interrelationships among these prices are depicted in Figure 4.

The three fund prices associated with DLR transactions are designed to recover from customers the full costs associated with stock funding for depot-level repair. The FAC is intended to recover the acquisition cost of a new DLR; it is calculated as the "last representative acquisition cost brought up to current day dollars."<sup>2</sup> The depot repair cost is intended to recover direct and certain indirect costs associated with depot-level component repair. The surcharge is intended to recover various other types of expenses associated with the fund. The depot repair cost and the surcharge are discussed in more detail below.

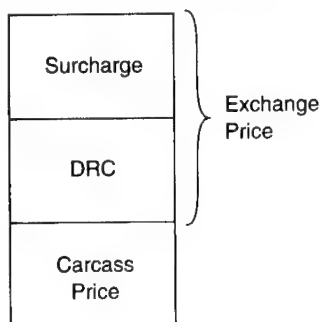
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<sup>1</sup>Similarly, the customer receives a credit equal to the standard price when returning a serviceable DLR and receives a credit equal to the carcass price when returning an unserviceable DLR without purchasing a replacement.

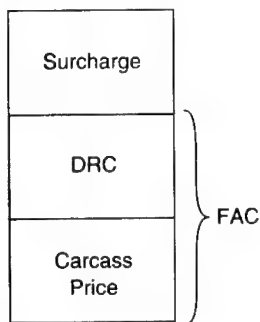
<sup>2</sup>Department of the Air Force, *Air Force Final Implementation Plan Stock Funding Depot Level Repairables*, draft, January 1993, p. 5-9.

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Standard Price = Exchange Price + Carcass Price



Standard Price = FAC + Surcharge



**Figure 4—Relationship Between Standard, Exchange, and Carcass Prices and FAC**

Standard price = Forecast acquisition cost (FAC) + surcharge

Carcass price = FAC - depot repair cost (DRC)

Exchange price = Standard price - carcass price  
= DRC + surcharge.

## DEPOT REPAIR COST

For the  $k$ th type DLR (referenced by national stock number, NSN) repaired at the depot, the depot repair cost is composed of direct costs, production overhead, and general and administrative (G&A) costs. The direct costs include average direct labor costs such as technicians and other shop-level personnel (calculated as cost per hour times standard repair hours) and the average cost of materials that go directly onto the specific end item being repaired. Included in the average direct material cost of each type of LRU are the costs of any of its component SRUs that must be replaced. The costs of the SRUs that are DLRs include (a) the exchange prices for those items purchased from the fund and (b) the direct labor and materials



(other than DLRs), production overhead, and G&A costs for those that are job routed.<sup>3</sup>

$$\begin{aligned} \text{Depot repair cost}_k &\equiv \text{average direct materials}_k \\ &+ \text{average direct labor}_k + \text{production overhead}_k + \text{G\&A}_k. \end{aligned}$$

Production overhead and G&A are costs associated with DMAG. Production overhead includes costs of all indirect activities controlled by the item's product directorate (e.g., indirect labor, scheduling, planning, indirect materials, and equipment depreciation).<sup>4</sup> The hourly rate for these costs is constructed at the shop level, and costs are allocated based on direct product actual hours (DPAH).<sup>5</sup> G&A costs include all costs not tied to a single product directorate (e.g., utilities, base support, and headquarters costs). With few exceptions, these rates are constructed at the directorate level. G&A costs are also allocated based on DPAH.

$$\text{Production overhead}_k \equiv \text{Production overhead rate} \times \text{DPAH}_k.$$

where

$$\begin{aligned} \text{Production overhead rate} &\equiv \text{hourly cost of (indirect labor} \\ &+ \text{schedulers} + \text{planners} + \text{indirect materials} \\ &+ \text{equipment depreciation} \\ &+ \text{other indirect product directorate activities)} \end{aligned}$$

$$\text{G\&A}_k \equiv \text{G\&A rate} \times \text{DPAH}_k,$$

<sup>3</sup>That is, the DRC does not include a surcharge for SRUs that are job routed.

<sup>4</sup>A product directorate is a major division of an ALC devoted to support of a specified group of NSNs. NSN groups are defined by major subsystem, weapon system, etc.; for example, the F-16 avionics product directorate at Ogden ALC.

<sup>5</sup>Direct product actual hours is an estimate of the actual time spent performing a direct labor task. The DPAH for a given NSN is calculated by dividing the direct product standard hours for that item by the direct labor efficiency (DLE) for that repair shop. The DLE for a repair shop is the total standard hours for all work in the shop divided by the actual hours for all work in the shop, that is, an average efficiency. See *Requirements/Funding Handbook*, Directorate of Financial Management, Hill Air Force Base, subsection 7-A.

where

G&A rate  $\equiv$  hourly cost of (utilities + base support + HQ  
+ other costs not tied to a single product directorate).

The depot repair cost portion of the DLR exchange price is subject to various errors. First, the calculation of direct labor cost is based on infrequently updated work standards and on average, rather than NSN-specific, efficiencies. Second, many indirect and G&A costs are not incurred in proportion to DPAH despite being allocated in this way. Third, the depot repair cost is based on data from two years earlier (see Chapter Four). For example, the depot repair cost portion of the FY 1996 DLR exchange price was calculated in FY 1995 and was based on FY 1994 data. The 1994 cost data were adjusted for inflation, pay raises, and other cost changes to the extent they were known.

For DLRs repaired by contractors, the depot repair cost is the estimated average price paid to the contractor.

### SURCHARGE

Support system costs associated with the SMAG are recovered from customers through a DLR price surcharge. These costs—totaling \$1.8 billion in FY 1995—include first destination transportation, inventory maintenance, depreciation, the Cost of Operations Division (COD), condemnations, inflation, and over/underrecovery of costs from the previous year (price stabilization).<sup>6</sup> These costs are allocated to an NSN's repair price in proportion to its FAC. The proportion,  $P$ , is the same for all DLRs and is calculated as

$$P = \frac{\text{total costs to be recovered}}{\sum_i n_i \text{FAC}_i},$$

where  $n_i$  is the forecasted demand for serviceables of NSN type  $i$ . Thus, the exchange price of a DLR of NSN type  $k$  is

<sup>6</sup>United States Air Force, *Defense Business Operations Fund: Fiscal Year 1997 Defense Budget Review*, September 22, 1995, p. 244.

Exchange price of  $DLR_k = \text{depot repair cost}_k + \text{surcharge}_k$ ,

where

$$\text{Surcharge}_k = P \cdot \text{FAC}_k.$$

Table 2 displays the breakdown of the surcharge by element for FY 1994–FY 1996. The three largest cost categories are the COD, condemnations, and price stabilization. The COD is a division of the Air Force Working Capital Fund. Its surcharge covers the costs of people, materials, and transactions supporting the Repairable Support Division of SMAG. Significant expenditures in the COD are for Defense Logistics Agency (DLA) issues and receipts, item managers, and other inventory control point costs. The condemnation surcharge covers the predicted annual cost of replacing all condemned DLRs, that is, those that cannot be repaired. The price stabilization surcharge recovers the difference between total SMAG costs and total SMAG revenues from the previous year and, in some years, recovers other costs as mandated by the Office of the Secretary of Defense (OSD) (Comptroller). It is typically positive when total costs were underrecovered during the previous year and negative when total costs were overrecovered.

**Table 2**  
**Elements of the RSD Surcharge**  
**(in percentage)**

Element	FY 1994	FY 1995	FY 1996
First destination transportation	0.48	0.01	0.01
Inventory maintenance	0.63	0.00	0.65
Depreciation	0.31	0.48	0.18
Cost of Operations Division	5.63	3.40	3.81
Condemnations	5.84	3.82	5.74
Price stabilization	1.46	3.81	-1.73
Inflation index	0.30	0.38	0.00
P	14.65	11.90	8.66

NOTE: The FY 1996 inventory maintenance surcharge recovers costs for the Joint Logistics Systems Center and certain software costs. These costs were not recovered by this surcharge in previous years.

In FY 1995, surcharge revenues were 47 percent of total RSD revenues. Because the ratio of an item's FAC to its depot repair cost varies greatly among NSNs, the surcharge as a percentage of the exchange price also varies greatly. For example, among a sample of avionics DLRs repaired at Ogden Air Logistics Center, we found that the FY 1995 surcharge ranged from 29 to 94 percent of the exchange price. To illustrate further, Tables 3 and 4 contain FY 1996 exchange prices and associated surcharges for a broad sample of relatively high-demand F-16 and C-130 DLRs. The first and last F-16 DLRs in Table 3 are noteworthy. For the receiver-transmitter in LANTIRN targeting pods, the depot repair cost is \$6,509 and the FAC is \$207,517, leading to a surcharge that is 73 percent of the item's exchange price. Conversely, the depot repair cost for the 20-millimeter automatic gun is \$8,046 and the FAC is \$8,476, leading to a surcharge that is only 8 percent of the item's exchange price.

### EXCHANGE PRICES ARE ARTIFICIALLY HIGH

The Air Force has incorporated broad categories of costs into DLR exchange prices that are unrelated to depot-level repair. In particular, the surcharge and, to a lesser extent, the depot repair cost for any DLR include elements that are unrelated to its rate of repair.

The price stabilization surcharge recovers costs that are unrelated to any repair performed during the current year. The COD surcharge includes many costs that are fixed with respect to rate of repair—for example, database managers. Furthermore, the COD costs that *are* related to rate of repair are not allocated directly to the items generating the charges. Instead, they are allocated in proportion to the FAC of each repaired item. For example, second destination transportation charges and DLA issues and receipts charges are incorporated into the COD surcharge rather than allocated directly to the items generating the charges.

Unlike the price stabilization and the COD surcharges, the condemnation surcharge recovers costs that are driven *entirely* by the rate of repair; however, the condemnation surcharge does not match the costs of the replacements with the types of DLRs that are condemned.

Table 3

## FY 1996 Exchange Prices: F-16 DLRs

DLR	Exchange Price (EP)	Depot Repair Cost (DRC)	Surcharge <sup>a</sup>	Surcharge as % of DRC	Surcharge as % of EP
Receiver-transmitter, LANTIRN targeting pod	\$24,480	\$6,509	\$17,971	276	73
Interface for bombing fire-control component	2,547	782	1,765	226	69
Oscillator, AN/ALQ-184 electronic counter-measures pod	12,395	6,441	5,954	92	48
LANTIRN computer module	18,296	9,571	8,725	91	48
Low-pressure turbine, F110 engine	39,103	20,724	18,379	89	47
Horizontal stabilizer	10,458	6,700	3,758	56	36
Brake stack kit	2,018	1,386	632	46	31
Power supply, AMRAAM	1,641	1,167	474	41	29
High-voltage power supply, AN/ALQ-184 electronic counter-measures pod	11,414	8,801	2,613	30	23
Aircraft leading edge	4,890	4,097	793	19	16
Augmentor nozzle flap, F-16 engine	770	681	89	13	12
High-pressure exhaust nozzle seal, gas turbine engine	693	613	80	13	12
20-millimeter automatic gun	8,780	8,046	734	9	8

<sup>a</sup>Surcharge = FAC \* .0866.

**Table 4**  
**FY 1996 Exchange Prices: C-130 DLRs**

DLR	Exchange Price (EP)	Depot Repair Cost (DRC)	Surcharge <sup>a</sup>	Surcharge as % of DRC	Surcharge as % of EP
Receiver-transmitter, RT-1504, AN/ARC-164 radio set	\$1,579	\$719	\$860	120	54
Radio receiver R101/A, ARN-6	1,077	651	426	66	40
Signal data converter, AN/ARC-164 radio set	172	103	69	66	40
Circuit card assembly, AN/ARC-164 radio set	447	289	158	55	35
Electronic control amplifier, E-4 automatic pilot	1,827	1,198	629	53	34
T-1307A radio transmitter, AN/ARC-164 radio set	811	574	237	41	29
7000 channel synthesizer, AN/ARC-164 radio set	736	556	180	32	24
Beam-scanning antenna, ARA-25	2,275	1,740	535	31	24
Altitude transmitting function, control, altitude, automatic pilot	684	521	163	31	24
Circuit card A10, control input, ARN-11	119	94	25	27	21
Cable assembly, AN/ARC-164	401	333	68	21	17

<sup>a</sup>Surcharge = FAC \* .0866.

$$\text{Condemnation surcharge}_k = \text{FAC}_k \times \frac{\sum_i \text{cost of replacements for NSN}_i}{\sum_i n_i \text{FAC}_i}.$$

As a result, low condemnation rate items are overcharged, and high condemnation rate items are undercharged. For example, avionics LRUs are rarely condemned and often have high acquisition costs. This combination of factors guarantees that the exchange prices for avionics DLRs reflect the costs of replacing other types of DLRs such as mechanical items. In the sample of avionics LRUs repaired at Ogden referred to above, the condemnation surcharge ranged from 9 to 30 percent of the exchange price.

Production overhead and G&A costs in the depot repair cost include elements such as base support and headquarters costs that are unrelated to the rate of repair.<sup>7</sup> Other elements of production overhead and G&A costs *are* related to the rate of repair and should not cause DLR exchange prices to be artificially high, on average. However, all production overhead and G&A costs are arbitrarily allocated to depot repair cost in proportion to direct product actual hours. Costs that are related to the number of repairs rather than the number of labor hours, for example, may be overallocated to repair activities that are relatively labor-intensive and underallocated to repair activities that use relatively few labor hours.<sup>8</sup>

We are unaware of any costs that have been left out of the exchange price other than pipeline inventory costs (discussed below). However, we do not believe that the exclusion of this cost category is sufficient to offset the inclusion of the non-repair-related costs. Thus,

<sup>7</sup>At Ogden ALC for FY 1995, the average direct cost per DPAH was \$45.08, the average G&A cost per hour was \$10.21, and the average production overhead cost per hour was \$26.75.

<sup>8</sup>For a clear discussion of the problems caused by inappropriate cost allocations and how the problems were solved in a relatively small organization, see Kovac and Troy (1991). (This paper is summarized in Appendix A.)

for the typical DLR, the exchange price will exceed the cost of depot repair.<sup>9</sup>

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<sup>9</sup>It is unclear whether or not exchange prices for items repaired by contractors are higher or lower than the costs associated with the transaction. Certainly the depot repair cost portion of the exchange price accurately reflects the marginal/variable cost incurred by the support system. However, the surcharge may over- or underrecover the contracting, management, and replacement costs that would be incurred.



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**PROBLEMS WITH THE CURRENT PRICING SYSTEM**

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In this chapter, we identify the principal problems attributable to the structure of DLR prices. We first explain how the current price system supports Air Force resource allocation decisions for most reparable while providing incentives for customers to make costly decisions for other reparable. We then discuss why the current structure of prices does not provide a useful view of costs. Finally, we identify the aspects of the current pricing system that can lead to under- or overrecovery of total fund costs.

**RESOURCE ALLOCATION DECISIONS**

**Level of Repair<sup>1</sup>**

When the Air Force implemented stock funding for DLRs, it structured prices to encourage wings to repair more of the items they are authorized and equipped to repair rather than sending them to the depot for repair. Part of the rationale for this decision was that wing maintenance personnel needed to meet wartime requirements are underutilized during peacetime. Given this rationale, pushing repair to the local level reduces costs.

There are both short-run and long-run consequences of structuring prices in this way. The current price system has succeeded in dis-

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<sup>1</sup>Many items have some repairs that are performed at the intermediate level and other repairs that are performed at the depot level. For simplicity, we will discuss level-of-repair decisions as if all repairs for a given NSN are performed at either the intermediate or depot level.

couraging wings from exchanging items that the wings are authorized and equipped to repair. However, the price system also encourages wings to find alternative sources of repair (local organic or contractor) for items that are supposed to be repaired at the depot level. In the long run, wings have an incentive to resist movement of repair from the local level to the depot level and even to seek authorization and resources to perform additional repairs. Customer commands, in addition to being responsive to wings, also have a financial incentive to resist migration of repair to the depot and to expand local and centralized intermediate repair capabilities.

This bias against depot-level repair is problematic in two circumstances. The first is when the cost of local repair is less than the DLR price but greater than the marginal/variable cost of depot repair. In the short run, wings compare the DLR price with the marginal cost of local repair. If the wing has access to a contractor who can do the repair or the wing itself has the equipment and personnel with the right skills, the marginal cost of local repair will almost always be less than the DLR price because the DLR price includes many costs not related to the rate of repair. However, the marginal cost of depot repair may be less than the marginal cost of local repair. Local repair in these cases would save O&M funds for wings while increasing support costs to the Air Force as a whole.

The Air Force has implemented constraints that are designed to prevent customers from taking actions simply to avoid paying the surcharge. The most significant constraint is that wings and customer commands are not authorized to change the level of repair of an item without the permission of the ALC managing it. To mitigate the incentive problem caused by artificially high prices, a wing/command must demonstrate that the cost of the alternative source of repair is less than the depot repair cost. We spoke to technicians at one base who had tenaciously pursued ALC approval to send a DLR directly to a contractor for repair (instead of going through the supply system) for a price that was the same as the depot repair cost but substantially lower than the exchange price. The ALC turned down the request because it appeared that the wing was simply trying to avoid paying the surcharge. After being turned down for cost reasons, the technicians argued their case based on supportability concerns. Their request was again turned down. This example illustrates

wings' desires to make decisions based on DLR prices and the constraints the Air Force imposes to try to prevent them from doing so.

This depot repair cost criterion would appear to stop customers from making level-of-repair decisions that are costly to the Air Force. Although we have no information on the extent of this activity, we have been told that wings sometimes turn to unauthorized alternative sources of repair on non-safety-of-flight items that are designated to be repaired at depot level, justifying this action as necessary to avoid excessive delays in obtaining serviceable units. In addition to potentially increasing marginal repair costs, this use of unauthorized sources of repair causes loss of information about failure rates and can lead to a loss of configuration control. We do not know whether wings would continue this behavior in the absence of artificially high prices, but the current price system reinforces it.

As we discussed in Chapter Two, job routing SRUs is a way for depot repair personnel to bypass the supply system and thereby avoid paying the surcharge on DLRs needed in repair. The *reported* cost of performing repairs (and, thereby, the depot repair cost) is lowered, making the repair shop appear more efficient. However, this activity results in a loss of information about failure rates because failures of reparable items are recorded only when carcasses are turned in to the supply system. Inaccurate failure rate information can lead to inappropriate decisions about inventories for those NSNs, which can ultimately increase repair times and/or inventory costs rather than decrease them. Although this information problem could be overcome through more sophisticated management systems, there is an additional problem associated with job routing. Because job-routed SRUs are returned to the LRU repair shop, there may be circumstances in which they are diverted from higher-priority use.

In the long run, commands compare total expected expenditures on depot repair with the total cost of local repair capability when deciding whether to agree to move selected repairs to the depot level or to increase local capability. (See case 1 in Appendix B.) Because DLR exchange prices typically exceed the cost of repair at the depot level, commands have no incentive to request reexamination of level-of-repair decisions for NSNs that are currently repaired locally. These decisions should be revisited when the factors underlying the original decisions change significantly, including frequency of repair, de-

pot repair cost and time, transportation cost and time, the cost of inventory to fill the pipeline, and the availability of manpower and other resources at the local level.<sup>2</sup>

The bias against depot-level repair is also problematic when a non-cost consideration, such as configuration control, led to the original decision to repair the item at the depot level. To the extent that commands and wings are driven by financial considerations, their decisions may be inconsistent with these other considerations. Unfortunately, customer recognition of the marginal cost of depot-level repair will not solve these problems.

Customers have incentives to pursue ways to avoid transacting with the fund even if they recognize that many of the costs included in the surcharge will still be incurred and must be recovered regardless. If customers are able to reduce their demand for depot repair services, under current policy the surcharge proportion will be increased for all DLRs, either contemporaneously or through the price stabilization surcharge the following year.<sup>3</sup> Thus, when a single customer reduces his demand, all customers share some portion of the costs that the customer avoided.

### Condition of Carcasses

Many unserviceable items can have more than one type of problem or have a problem with varying degrees of severity. Some LRUs contain several SRUs, any number of which may need to be repaired or replaced. Mechanical items (e.g., hydraulic pumps) may need moderate adjustments or extensive repairs.

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<sup>2</sup>New Air Force Lean Logistics initiatives are leading to a transportation-based logistics system. In the future, wings may have many fewer supply and maintenance personnel at base level, relying instead on rapid transportation between the deployed unit and a centralized repair facility for resupply of reparable components. (Lieutenant General John Nowak, Air Force Deputy Chief of Staff for Logistics, May 1995, remarks at RAND.)

<sup>3</sup>If the reduction in demand is unanticipated, then costs will be underrecovered during the current year, thereby increasing the price stabilization surcharge the following year. If the reduction is anticipated, the surcharge percentage (multiplied by each item's FAC) will be increased for the current year to avoid underrecovery of costs.

Customers often can influence the condition in which unserviceables arrive at repair facilities. For example, maintenance personnel can control the times between the removal and replacement of mechanical items (assuming they do not affect safety of flight), thereby changing the average repair needs of carcasses. When LRUs have multiple SRUs, customers can consolidate broken SRUs prior to exchanging the LRU carcass for a serviceable one. Also, for items requiring one or more of several possible repairs, customers can select less costly repairs to perform locally and send the rest to the depot.

Under the current DLR price structure, the depot repair cost portion of the exchange price is based on the average repair cost two years earlier and does not depend on the condition of the returned carcass. Thus, if by turning in carcasses in relatively poor condition, customers can reduce the number of exchanged DLRs, they can reduce their current expenditure on DLRs. The total repair cost to the Air Force increases if the higher repair cost per item outweighs the smaller number of repairs (and decreases otherwise).

Wings can worsen the condition of carcasses exchanged for serviceable items by extending time between maintenance of mechanical items. This practice generally leads to more expensive repairs and more condemnations.<sup>4</sup> (See case 5 in Appendix B.) Similarly, wings can consolidate failed SRUs to reduce the number of LRUs they exchange. (See case 4 in Appendix B.) Customers can also save O&M funds on items with distinct repair needs by performing low-cost repairs locally and sending only the expensive repairs (i.e., those repairs that cost more than the DLR exchange price) to the depot level. (See cases 2 and 3 in Appendix B.)

Intermediate-level F-16 avionics screening provides an example of the latter two sources of savings for wings. The first step in the repair of a typical avionics LRU is to screen the box for broken SRUs, electronic cards in this case. The customer is charged the exchange price even if the depot cannot duplicate the failure reported from the field and returns the unit to stock or back to a base. By using avionics in-

<sup>4</sup>There will, of course, be some DLRs that are found not to be degraded by increased use before removal and replacement. Clearly, there can be mistakes in the initial determination of optimal inspection intervals or utilization rates. However, providing incentives to exceed these parameters is not the best way to test their optimality.

intermediate test stands, wings can perform the same “cannot duplicate” (CND) screening and exchange only those LRUs found to have broken electronic cards. This screening also provides an opportunity for the wing to consolidate failed cards in a smaller number of LRUs, reducing the total number of LRUs exchanged. The amount the wing saves by screening and consolidating is equal to the sum of the exchange prices of the units it avoids exchanging less the cost of staffing and maintaining the screening equipment. Whether this screening also saves money for the Air Force depends on the trade-off between the cost of wing-level screening resources (less the reduction in pipeline inventory) and the transportation and depot screening costs.<sup>5</sup> Camm and Shulman (1993) found that CND screening at four bases, each with 72 aircraft, would cost the Air Force approximately \$2.7 million per year more than screening only at the depot, because of underutilization of test stands at base level.<sup>6</sup> In spite of evidence that local screening increases Air Force support costs, ACC has chosen to retain avionics test stands in the field because this capability saves command funds.

The wings’ incentives to engage in these activities depend on the magnitudes of exchange prices relative to local costs. The lower the exchange prices, the less wings save by extending use of DLRs, consolidating broken SRUs, and sorting between less expensive and more expensive repairs. For example, if avionics DLR prices were set at the cost of depot screening, wings would have little financial incentive to perform CND screening at base level and to consolidate broken SRUs (unless of course the avionics LRUs are in short supply). However, because the depot repair cost is based on historical carcass conditions, to the extent wings do engage in these activities exchange prices will rise to reflect the customer-induced increased repair costs. In turn, these higher prices increase the financial incentives for customers to engage in these activities.

We received mixed information from discussions with Air Force maintenance personnel about their responses to DLR prices. Some maintenance shops remain faithful to Air Force maintenance and supply guidelines for DLRs while others exhibit the behavior dis-

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<sup>5</sup>See Chapter Five for a discussion of pipeline inventory.

<sup>6</sup>See Camm and Shulman (1993), p. 7.

cussed here. Unfortunately, we are unaware of any data that can provide information about the extent of these responses to DLR prices. We note only that current prices create incentives for such behavior.

### VISIBILITY OF COSTS

The support system incurs many costs in addition to direct repair costs.<sup>7</sup> There are costs associated with the existence of the support system itself (e.g., base operating support for ALCs), maintenance of a weapon system (e.g., system program office staff at ALCs), support of a given NSN (e.g., item managers, equipment specialists), on-demand services offered by the depot (e.g., selected engineering support), and provision of wartime surge capabilities (e.g., equipment and manning beyond peacetime requirements). These costs must be recovered from customers or from direct appropriation.<sup>8</sup>

Support service costs that are not related to the rate of repair are currently included in DLR prices, making the actual costs of individual supply and repair services less visible to customers and other decisionmakers. This arbitrary allocation of support costs is misleading to customers and can result in the provision of services that are valued at less than their costs. DoD recognizes this problem:

[A] Military Service may be requiring support costs that are not of high priority, but are incurred because the requirer is not required to justify the funding in the budget. The additional costs may also not be visible to either the requirer or the decision makers. (*Defense Management Report Decision*, No. 971, p. 2)

Despite this recognition, the visibility of these support costs remains low.

When a customer requests a budget for DLRs, the customer becomes a de facto advocate for the provision of all the services that are funded by that budget. Thus, covering the costs of support services

<sup>7</sup>Direct repair costs include direct labor and materials, pipeline inventory costs, transportation costs, and so forth.

<sup>8</sup>When a portion of a working capital fund activity's plant is purposely set aside as idle capacity, a direct appropriation can be requested. (DoD 7000.14-R, p. 65-2.)

by incorporating them in DLR prices causes customers to be the advocates for the *aggregate* level of these services but provides customers with no vehicle to discriminate among them.<sup>9</sup>

The invisibility of these costs to customers raises additional problems on the suppliers' side. First, suppliers are provided with little information about the value of their services and, thereby, about whether the level of these services should be changed. Second, incentives to reduce the costs of providing these services must come from sources other than the reaction of customers to prices.

Allocating the surcharge costs in proportion to the FAC also creates problems for accurately identifying weapon system and command operating and support costs. For example, weapon systems with relatively more avionics bear a disproportionate share of condemnation costs because of the low rate of condemnation and high acquisition costs of avionics equipment. Thus, decisions about changing flying programs or eliminating weapon systems from the active inventory can be skewed by inaccurate estimates of the cost consequences of the alternatives.

## RECOVERY OF TOTAL COSTS

The nonzero price stabilization surcharge is evidence that matching costs with revenues is problematic. Some sources of the mismatch between costs and revenues are difficult for the Air Force to control; others stem from the structure of DLR prices and can be avoided.

Demand forecast errors are a source of differences between costs and revenues. Major sources of forecasting errors are "(a) substantial variability in spares demands, even in peacetime (statistical uncertainty), and (b) instability in force structure, force beddown, flying hour programs, funding profiles, item reliabilities, and other item characteristics (state-of-the-world uncertainty)."<sup>10</sup> Depot repair-

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<sup>9</sup>There is a perception that customer commands are more likely to get political backing for support services than is the provider of the support services. It is easier to justify funding support services when the customer demonstrates the importance of the services for combat readiness through willingness to pay for them than when the provider asserts that it is important to provide them.

<sup>10</sup>See Adams, Abell, and Isaacson (1993), p. 1.



related resources (maintenance manpower, equipment, and materiel) must be budgeted for and procured in advance of the demand for these resources.<sup>11</sup> Therefore, it is difficult to avoid over- or under-recovery of costs arising from unanticipated changes in demand.

The current structure of exchange prices can introduce substantial differences between costs and revenues in the presence of demand forecast errors. The costs of operating inventory control points, condemnations, and the previous year's imbalance between revenues and costs are included in the DLR surcharge; therefore, recovery of these costs is dependent on the accuracy of forecasted demands for repair. Costs included in the surcharge are roughly one-half of all the costs that need to be recovered. If demand falls short of (or exceeds) expected levels, then these costs are not fully recovered (or are over-recovered).

The age of the data used for cost estimation is another source of imperfect cost recovery that is difficult to avoid. DoD's budgeting schedule requires that command budgets be constructed well in advance of the execution year. The data used to estimate the depot repair cost portions of exchange prices are based on the resources used in the fiscal year preceding construction of command budgets. Therefore, exchange prices in any year are based on average repair costs from two years before.<sup>12</sup>

Because of this time gap, unanticipated changes in average repair costs can lead to a mismatch between revenues and costs. The prices of material and labor used in the repair process can change as a result of exogenous factors, and the average difficulty of repair can change as a result of customer responses to DLR prices. For example, the recent increase in the number of unserviceable SRUs per F-16 avionics LRU was unanticipated and arose from conscious decisions at wing level to avoid high avionics DLR prices. As a result, the calculated depot repair cost was too low.

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<sup>11</sup>Resources that are readily available in the commercial market need not be procured in advance.

<sup>12</sup>Although the depot repair cost portion of the exchange price is based on repair costs from two years earlier, the price stabilization surcharge reflects over- or underrecovery of costs from the year immediately preceding the execution year.

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## RECOMMENDATIONS

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In this chapter, we recommend changes to the DLR price structure and the cost recovery method that will yield a more flexible price structure that can accommodate changes in support strategies. This price structure will reduce the misalignment of customer incentives and Air Force costs discussed in the preceding chapter, and improve the Air Force's ability to achieve proper allocation of support resources. In addition, implementation of our recommendations will increase the visibility of various support costs and facilitate their recovery.

Appendix A contains a supporting discussion of the recommendations from the economics and accounting literatures for optimal internal transfer prices.

### PRICING STRATEGIES

Price systems can be designed to support various levels of decision making and to achieve different ends. One approach is to structure prices to enforce *centrally determined* strategic decisions. Here, prices skew customers' incentives toward taking predetermined "best" actions. Another approach is to promote *customer* decision-making—that is, structure prices to give customers incentives to make decisions that minimize the costs of meeting Air Force support goals. In either approach, customers will make decisions based on the costs they face for each support alternative; however, in the latter case, customers face the costs to the Air Force for each alternative.

In principle, either approach to decisionmaking and its attendant price structure could be designed to lead to the same support outcome. The conditions required are availability to both central authorities and customers of accurate information on costs and other considerations, stability of these factors over time, and alignment of customers' and central decisionmakers' goals. When these conditions are not satisfied, one approach will be preferred over the other.

When information is less readily available to the customer than to central decisionmakers (e.g., when a new reparable component is introduced to the Air Force), centralized decisionmaking is preferred. For this reason, the Air Force makes initial level-of-repair decisions centrally. Over time, customers may develop better information as they gain experience with a system because they have a greater ability to detect changes in local repair costs, conditions of use, and frequency of failure. Thus, there are payoffs from setting prices *as if* customers were making the decisions, providing them with incentives to identify level-of-repair decisions that should be revisited.<sup>1</sup> However, when customers' and central decisionmakers' goals are not aligned—maybe there are noncost considerations that customers should, but are unlikely to, account for—prices must be adjusted to reflect them. For example, if a DLR should be repaired centrally for mobility reasons, the price should be set so that transacting with the fund is the least expensive option for customers.

Under DoD financial management policy, all costs associated with stock-funded activities must be recovered from customers. However, the costs that have to be recovered are not always equal to the costs customer actions impose on the Air Force, and these latter costs are the costs germane to current decisions. For example, when an item is in excess supply, the price that gives customers the right incentive may be close to zero because broken items will not (and should not) be repaired or replaced. However, under current policy, the acquisition costs of the excess serviceable items must be recovered despite the fact that these costs are unaffected by current repair decisions.

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<sup>1</sup>If an item is only repaired locally and, hence, there is no DLR price, customers will not have sufficient information to reassess the level-of-repair decision for that item. If the depot also does not have the information to reassess, automatic periodic reviews may be needed.

There are two general approaches to recovering costs that are unaffected by current decisions. One approach is to increase DLR prices sufficiently to recover these costs; the other is to recover the fixed costs through separate charges. The Air Force recovers fixed costs by increasing DLR prices, allocating these costs to prices in proportion to the acquisition cost of DLRs. As discussed in Chapter Four, this approach has the disadvantage of creating a wedge between prices and the costs that customers impose on the supply system; accurate visibility of costs by NSN or other aggregation is not possible. It also has the disadvantage of making customers advocates of services that they may value at less than their cost.<sup>2</sup>

Alternatively, fixed costs can be apportioned to prices in inverse proportion to the sensitivity of demand to prices. This allocation scheme—termed “Ramsey pricing”—distorts decisions less than the Air Force’s approach.<sup>3</sup> For example, items with potential alternative sources of repair would be priced at the market price (which will be close to marginal cost in competitive markets), but the prices of items that can only be repaired at the depot would be set much higher than marginal cost to recover fixed costs.<sup>4</sup> Even though some prices might be seen as excessively high, level-of-repair decisions are unaffected because wings have no alternative sources of repair. However, Ramsey pricing also has several disadvantages. As with current Air Force DLR pricing, Ramsey pricing bundles the costs of DLR repair services with other services. Also, accurate visibility of costs by NSN or other aggregation is not possible. Finally, it has extensive information requirements—which items are sensitive to prices and which are not—and might be difficult to administer.

The approach we recommend is to establish separate charges to customers for costs unaffected by current repair decisions. This approach would more closely match DLR prices with marginal repair

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<sup>2</sup>See Eccles (1985, 1991) and Eccles and White (1988) for a discussion of the use of full cost transfer prices by commercial firms.

<sup>3</sup>For a discussion of Ramsey pricing, see the appendix in Camm and Shulman (1993).

<sup>4</sup>The Air Force uses a similar strategy in the transportation business area (called the TRANSCOM Working Capital Fund); it sets airlift rates to be competitive with commercial carriers’ rates. However, this pricing scheme differs from Ramsey pricing in two ways: costs exceeding airlift rates are recovered through direct appropriations rather than from customers and airlift rates may be less than marginal cost.

costs and would improve visibility of other costs. This method of cost recovery is not perfect; there can be ambiguity about whether selected costs are completely fixed or vary with the rate of repair, and the establishment of additional charges places burdens on the accounting systems. However, recovering these costs separately from DLR prices helps customers make decisions that are cost-effective for the Air Force and allows customers more flexibility in the long run in choosing the services they wish to pay for.

## RECOMMENDED STRUCTURE OF DLR PRICES

Our pricing recommendations are based on two central ideas:

*Decisionmakers can make the most cost-effective resource allocation choices when the prices they face reflect the costs those choices impose on the Air Force.*

*The costs of all stock-funded activities should be recovered from customers.*

We apply these ideas to stock funding of DLRs in two ways. First, customers should be charged separately for services and fixed costs unrelated to the rate of repair. Second, DLR prices should reflect only the additional (marginal) cost incurred by the support system in response to a customer transaction.<sup>5</sup> The exchange price should include only those costs that vary with the rate of repair and, under certain conditions, should reflect the condition of the unserviceable carcass.

Our specific recommendations concerning the structure of DLR prices are presented in order of priority and are summarized in Table 5 at the end of the chapter. Technical analysis supporting our recommendations is found in Appendix B.

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<sup>5</sup>In the same spirit, see Hirshleifer (1956), Benke and Edwards (1980), Kaplan and Atkinson (1989), and Rogerson (1995).

## DLR Prices Should Not Include a Surcharge

*Recommendation 1: Costs unrelated to rate of repair should be recovered from customers, but not through DLR prices.*

Many support costs are related to repair but are fixed during the year. Examples include costs that were underrecovered the previous year, capital equipment, system program office staffing at ALCs, and technological and industrial support of product directorates. There are also variable costs that are unrelated to the rate of repair such as equipment specialist services, engineering support, software maintenance and development for operational applications, and other services provided on demand.

Recovering these costs from customer commands through charges that are independent of DLR prices has three advantages over the existing approach. First, the wedge between marginal costs and DLR prices is virtually eliminated, thereby reducing customer incentives to take actions that increase costs to the Air Force. Second, the visibility of the costs of strategic support decisions and customer support services can be improved. In the case of customer services, this visibility allows customers to determine if the benefit of a given service warrants its cost and, when it does, establishes the customer as a proponent. Finally, the dependence of cost recovery on the accuracy of demand forecasts is significantly reduced, improving the match between costs and revenues.<sup>6</sup>

*Recommendation 1a: Fixed or sunk costs should be allocated to customer commands through periodic charges according to the cost source to the extent feasible.*

By definition, fixed costs are not affected by wing behavior. Thus, fixed costs that can be linked to individual customer commands should be allocated to those commands. Some of these costs result from previous long-run strategic decisions made by commands and thus influence future decisions. For example, NSN-specific costs—costs that would disappear if that item were no longer repaired at

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<sup>6</sup>This is a common strategy in public utility pricing. For example, Southern California Edison has a two-part price structure that consists of a flat fee each billing period to cover the cost of basic services and a charge per kWh to cover variable costs.

depot level—should be charged to commands in proportion to use. Weapon system-specific costs should be identified as such and charged to the commands operating the weapon system in proportion to ownership, thereby facilitating the evaluation of the weapon system's annual costs. Losses/gains from the previous year should be allocated among the commands according to the source of the under- or overrecovery to the extent this can be determined. Those costs that cannot be linked to decisions made by individual commands will need to be allocated arbitrarily among all the customer commands.

The components of the command charges need to be clearly identified because many of these costs are not fixed over a horizon of several years—they are affected by level-of-repair decisions and decisions about the continuing presence of specific NSNs and weapon systems in the Air Force inventory.

**Implementation.** Because command budgets are set at the beginning of each fiscal year, the frequency of payments from the commands should not influence decisionmaking. That is, as long as the total amount to be paid during the year is fixed, it should not matter whether a command makes one lump-sum payment at the beginning of the year, four equal quarterly payments, or more frequent payments. The payment plan that is easiest to implement should be adopted.

*Recommendation 1b: Prices should be established for customer services that are unrelated to the rate of repair.*

Currently, customers do not see the costs of individual nonrepair services they demand when these costs are recovered through the surcharge. (See examples of such costs in Recommendation 1 above.) Therefore, customers are not able to weigh the benefits of these services against their costs. Prices reflecting the costs of providing these services would generate improved information about which services should be expanded and which reduced or eliminated.

## DLR Prices Should Reflect the Marginal Cost of Transactions

*Recommendation 2: Exchange prices should include all costs that vary with the rate of repair and no other costs. Similarly, standard prices should include all costs that vary with the rate of acquisition and no other costs.*

If the corporate Air Force and internal customers share the same goals, customer incentives are more closely aligned with those of the Air Force when DLR prices reflect only the additional costs that will be incurred in a transaction. Customers will not necessarily choose the lowest cost repair when there are noncost considerations; however, they will see the true costs and benefits of repair at each level and will make trade-offs that are appropriate not only for themselves but for the Air Force as a whole.

Costs that vary with the rate of repair include direct material and labor, pipeline inventory, transportation, and condemnations (when necessary). There are also some indirect and overhead costs that can be nonarbitrarily allocated by NSN to the rate of repair. For example, if the number of payroll personnel varies with the number of repair personnel and the number of repair personnel varies with the rate of repair, then payroll costs should be treated on a per-repair-person basis just as direct labor costs are.

Costs that vary with the rate of acquisition of new DLRs include purchase price (FAC), procurement pipeline inventory, transportation, and all indirect and overhead costs that can be nonarbitrarily allocated by NSN. These costs will typically be incurred when customer purchases of serviceable DLRs result in the acquisition of new DLRs to replenish the inventory.

Pipeline inventory costs currently are not visible to customers, although they are clearly related to the rate of repair. Except for items in long supply, unserviceable DLRs create demands for additional inventories to fill the pipelines for those items. The longer the average time items remain unserviceable, the greater the pipeline demand.

The DLR exchange price should include a pipeline inventory charge to recover the cost of the inventory necessary to support the average number of days between the time an unserviceable item leaves the



wing until it is returned to supply as a serviceable item. Similarly, the standard price should include a pipeline inventory charge to recover the cost of the inventory necessary to support the average number of days between the time that an item that will be condemned leaves the wing until a new unit is procured and entered into the supply system.<sup>7</sup>

The surcharge recovers the cost of transporting DLRs between the depot and bases. Rather than arbitrarily allocating these transportation charges through a surcharge, the costs should be borne by the individual customers imposing the costs on the support system. Thus, transportation costs should be included in DLR prices on an NSN-by-NSN basis.

**Implementation.** When pipeline inventory costs are small relative to marginal repair costs, the cost of including pipeline inventory charges in DLR prices may exceed the benefits. (Typically, this will apply to long-lived and/or short-cycle-time items.) On the other hand, if it is possible to calculate pipeline inventory costs using automated financial systems, it may be less costly to include these costs in prices for all DLRs rather than selected ones.

Because transportation times and charges vary little within a regional theater relative to between theaters, it may be that only one pipeline inventory cost and transportation cost per theater should be calculated for each NSN.

*Recommendation 2a: When customers cannot affect the condition of a returned carcass, the DLR exchange price should be set equal to the average cost of a transaction for the NSN and not reflect the condition of the carcass. This average cost of the transaction should include repair costs and replacement costs, weighted by their respective probabilities. Thus, the carcass price should equal the standard price minus the average cost of a transaction.*

Customers can affect the condition of a returned carcass in three primary ways: excess usage, local organic repair (which enables

<sup>7</sup>When only a fraction of the condemned items is replaced, the procurement pipeline inventory should be weighted by that fraction.

cannibalization and sorting), and local contract repair. When customers cannot influence the condition of a carcass arriving at the depot—for example, an avionics LRU that is sealed and not subject to wing-level screening or an LRU with no alternative source of repair—the exchange price for that NSN should be set equal to the average marginal repair cost plus associated costs that vary with the rate of repair. Charging different prices depending on the carcass condition will not influence carcass conditions in these cases and may be costly to implement.<sup>8</sup>

The replacement costs of condemned items can be recovered in three ways. In the short run, all three approaches would recover replacement costs. However, these approaches differ in their ease of implementation and the incentives they provide commands to desire ownership of DLRs.

- One approach is to charge each wing the replacement cost when a returned carcass must be condemned and replaced. This might lead wings or commands to insist on ownership of specific DLRs. For example, if an item can be repaired only a limited number of times before it must be condemned, then commands may want to protect themselves from paying for a condemnation when other commands were responsible for previous repairs of that particular item.
- Another approach is to recover replacement costs through periodic charges to customer commands based on flying hours (possibly adjusted for each command's past replacements per flying hour). This would avoid the problems raised above while ensuring that condemnation costs are recovered from customers.
- A third approach is to average the NSN-specific replacement cost into the exchange price paid by the wing. This approach also avoids problems raised in the first approach but is easier to implement within the current financial system than the second approach. However, there is the possibility that averaging the cost

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<sup>8</sup>Carcass condition may be affected by mission rather than behavior, and for these NSNs there should be command-specific exchange prices. For example, equipment in one command may be subject to salt air and, thereby, may always require more extensive repairs than the same equipment operated by other commands.

of replacement items with repair costs may provide customers with incentives to seek to *create* alternative sources of repair that cost less than the exchange price but perhaps more than the actual cost of depot-level repair. If this behavior emerges in response to an average cost exchange price, the second approach should be used.

*Recommendation 2b: When customers can affect the condition of a returned carcass (e.g., through excess usage, cannibalization, or sorting), the DLR exchange price should reflect the condition of the carcass. When a carcass is returned alone rather than through an exchange, the carcass price should reflect the condition of the returned carcass.*

When a customer can influence which of several possible repairs are necessary, the exchange price the customer pays should reflect the cost of each of the necessary repair activities. These repair activities include separable repairs as well as repairs with varying degrees of difficulty. For example, the exchange price of an avionics LRU should include only the cost of screening if the technician cannot duplicate the failure. However, in the case of a failure, there should be an additional charge for each SRU repaired. Similarly, if a customer requests a serviceable unit but keeps the carcass longer than the period allowed for exchanges (the customer is charged the standard price for the serviceable unit requested), then the carcass price should reflect its condition if that customer returns the carcass at a later date.

Charging customers in this way should cause them to adversely affect carcass conditions only when that is the most cost-effective strategy for the Air Force.<sup>9</sup> In addition, charging according to the

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<sup>9</sup>There is the possibility that the depot repair shop could overstate the required repairs in order to artificially inflate the demand for its services. (We have not been told of any such cases.) This might occur when the shop is not busy; there is no incentive to do so otherwise. However, this behavior is no more likely under the recommended pricing strategy than under the current one. Under the current system, if the average repair cost reported during the year is higher than the one used to set the current DLR exchange price for an item, the estimated depot repair cost will rise, and the shop will suffer no long-term consequences unless there are alternative sources of repair. Under the recommended strategy, the wing could receive a report on what repairs were deemed necessary that could serve as an external check.

condition of the returned carcass would eliminate the necessity of adjusting the exchange price to account for changes in the average condition (and cost) of repair, an adjustment that takes two years to achieve.

Similarly, when the customer can affect the condemnation rate of a DLR, the customer should pay the standard price if the returned carcass must be condemned. We recognize that there is a possibility that customer commands may demand ownership of serial numbers in response to such a policy. In this case, the cost of customer-induced condemnations must be weighed against the increased administrative costs of a repair-and-return system.

**Implementation.** This recommendation requires tracking a carcass from the base to inspection at the repair facility. It does not require a repair-and-return policy (unless customers demand serial number ownership). We say "inspection" rather than "completion of repair" because the price could be established when the needed repair is determined. (However, for some complex items that are difficult to diagnose, perhaps because of multiple failures, the full cost of depot repair may not be known until the repair has been completed.) The charge for each distinct repair activity should represent a standard cost of that activity (e.g., a fixed charge for the repair of a given SRU) rather than the actual material and labor used to make the repair. Thus, assuming the customer cannot affect the time it takes to accomplish each identified type of repair, variability in individual repair times should be ignored. Similarly, if there are several levels of difficulty of repair for a mechanical item, the charge for each should be a standard cost. Because there is a limited number of distinct repairs for each NSN, there should be a limited number of prices for each NSN.

Clearly, this pricing recommendation should be adopted only for selected NSNs: those for which incentives cause significant adverse selection problems. The Air Force could determine the cost and effectiveness of this recommendation by first implementing it for a few "pilot" NSNs.

The source of DLRs arriving at ALCs can be identified. In addition, at least one ALC, the Ogden ALC, can track repairs of avionics LRUs by serial number. (Our understanding is that these data are for the F-16,

F-15E, and F-117.) However, currently there is no method for connecting this information with a charge to the customer.

To reduce the financial uncertainty facing the wing, pricing should take place in two stages. First, the wing should be charged the average marginal repair cost at the time it exchanges an unserviceable for a serviceable DLR. The wing's account then should be debited or credited to reflect the condition of the carcass as soon as practical. With a fully automated system this could be done as soon as the necessary repairs are determined. Without such a system, the goal should be to adjust the charge to the wing within the same fiscal year so that the wing's costs are tied to its actions. This may prove difficult for items with lengthy times between entry into the supply system and induction into repair. However, under the Air Force's lean logistics initiatives, unserviceable DLRs will be inducted into repair soon after they are returned to the supply system, so the lag between the original billing and identification of needed repairs should be minimal.

*Recommendation 2c: The exchange price for a DLR in excess supply should be discounted based on the length of time before repair or replacement is necessary.*

As the number of aircraft in the force structure declines, the Air Force may find itself with enough spare serviceable DLRs of a given type to satisfy demands for a year or more without repairing or replacing carcasses. Because repair can be deferred until the excess serviceable inventory is drawn down, the DLR exchange prices should be less than the costs that would be incurred if those DLRs were repaired immediately.<sup>10</sup> With each purchase of a serviceable item from the inventory, the date that repairs become necessary to satisfy demand for the item moves closer. Thus, the true marginal cost of each purchase is the discounted present value of the additional future repair costs imposed upon the supply system. (See the end of Appendix B for a derivation of this cost.)

The Air Force may choose to repair a portion of the returned carcasses each year to maintain technicians' repair skills. If it does so,

<sup>10</sup>The Army has adopted a similar strategy with its "Reduced Price Initiative" that lowers the standard price of some items that are in long supply.

then the DLR exchange price should be a weighted average of the marginal repair cost and the discounted cost described above. The weights are the proportion of carcasses repaired immediately and the proportion deferred, respectively.

In extreme cases, the Air Force may find itself with enough spares of a given type to satisfy demands for the remaining lifetimes of selected aircraft mission/design/series (MDS). In these cases, it would be a waste of resources for anyone—wing or depot—to repair or replace unserviceable carcasses (except in the unlikely event that the cost of local repair is exceeded by the cost of transporting serviceable units from the depot to the wing). The price charged for a serviceable item in long-term excess supply should reflect only the cost of the actions taken in response to the purchase and not include any charge for repair or replacement.<sup>11</sup> Doing otherwise could provide incentives for wings to seek alternative sources of repair, thereby increasing total costs to the Air Force.

Excess supply of NSNs could result from poor procurement procedures. Prices should reflect these excess supplies not only to prevent customers from taking repair actions that cost the Air Force money, but also to highlight the cost of poor inventory management.

**Implementation.** An automated financial system would require a discount rate, an estimate of the demand rate, the number of serviceables in excess supply, and proportions of exchanged carcasses to be repaired to compute these prices. In the absence of an automated system, prices should be adjusted in those selected cases in which the cost consequences of distorted incentives are largest. The distortion is positively related to the discount rate, the size of the excess supply, and the availability of low-cost local repair alternatives.

<sup>11</sup>An exception would be if the Air Force could sell the DLR elsewhere or return it to the manufacturer for a refund. In this case, the sales or refund value of the item would be a current cost and should be included in the DLR price.

### **Wings and Depot Repair Shops Are Not Customers for Some Depot Services**

*Recommendation 3: Headquarters U.S. Air Force should be the customer for services that may be undervalued by customer commands.*

There may be some costs unrelated to the rate of repair that should not be recovered from customer commands. For example, much of the engineering services focus on extending the life of basic airframes. With tight budgets, commands might let some of the long-term engineering services (e.g., configuration management and lead-the-fleet testing programs) atrophy rather than cut back on the current flying-hour program. If this is not the appropriate decision from the Air Force point of view, then Hq USAF should be considered the customer and pay for the services. More generally, services considered valuable to the Air Force but at risk of being undervalued by customer commands should be paid for by direct appropriation.<sup>12</sup>

### **Pipeline Inventory Fees Can Be Used for Rewards and Penalties**

*Recommendation 4: Pipeline inventory fees should be used to penalize delays and reward reductions in pipeline times at wings and depot repair shops.*

Pipeline times are affected by how the unserviceable item is handled within the supply system and in repair as well as by the actions of customers. Pipeline inventory costs increase when repair processes are delayed. Wings increase pipeline inventory costs when they delay turning in carcasses after drawing serviceable units from supply.

Wings should be charged an additional fee, separate from the exchange price, for each day they delay turning in a carcass after receiving a serviceable unit.<sup>13</sup> These additional fees will encourage

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<sup>12</sup>We are indebted to our colleague Ray Pyles for this point.

<sup>13</sup>See case 4 in Appendix B for a definition of the daily pipeline inventory cost for an NSN.

wings to weigh the costs of turning in unserviceable items concurrent with drawing serviceable ones versus delaying to effect cannibalization. Similarly, by charging repair shops (or other responsible parties) for delays and rewarding reductions in repair times (relative to the average times included in the exchange price), pipeline inventory charges can promote efficient repair processes.

**Implementation.** Fees charged to wings for delays in returning unserviceable carcasses must not be collected through reduced carcass prices. Such a reduction in carcass prices would reduce incentives for turning in long-delayed carcasses. It may be necessary to accumulate these fees off-line and charge them on a monthly or quarterly basis. The key is that wings see the costs of their actions during the same budget year as much as possible. However, for a given delayed carcass, a wing should incur no additional pipeline fees once cumulative fees associated with that transaction equal the carcass price.<sup>14</sup>

In cases of significant improvements in depot repair times, prices should be adjusted soon after the improvement to reflect the new pipeline times. If prices are not updated off-line, depot shops will receive rewards for performing at what should be considered their normal level for up to two years after the change. Also, customers will not receive accurate cost information through prices.

In the absence of an automated billing system, it is likely that the benefits of pipeline inventory fees will not justify the implementation expense.

## GENERAL IMPLEMENTATION ISSUES

These recommendations vary in the extent of changes to the financial management system they require. The most significant gains would come with the least costly change—excluding the fixed costs in the surcharge from DLR prices and tying the variable costs in the

<sup>14</sup>We recognize that this method of implementing pipeline fees will cause a customer who loses a carcass to incur charges for the transaction that are greater than the standard price of the item. However, we do not perceive this to be a likely scenario. This situation could be avoided by deducting the pipeline fees from the carcass price. We chose not to do this in order to provide customers with the full incentive to return a carcass at any point after a transaction has occurred.



surcharge (e.g., DLA issues and receipts, condemnations) to the NSNs that generate them.<sup>15</sup> Even recovering these fixed costs through arbitrary charges to commands—e.g., in proportion to total demand—would improve the alignment of Air Force costs and command incentives.

The United States Transportation Command (TRANSCOM) Working Capital Fund, formerly DBOF-T, provides an example of a financial management system that does not recover all costs through transaction prices to customers. As discussed above, airlift rates are set to be competitive with commercial carriers. Remaining costs are recovered through direct appropriations.<sup>16</sup>

Price system recommendations that require more significant expenses should be implemented on a small scale to determine if they have the desired effects on decisionmaking. For example, charging differential prices for a few DLRs whose states of repair are most influenced by customer behavior would provide a basis for evaluating the benefits of this aspect of DLR pricing. However, any introduction of differential prices must be viewed by customers as being permanent. Otherwise, only short-run behavior will be influenced.

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<sup>15</sup>Tying *all* variable costs to the NSNs that generate them is not easy, even without the refinements associated with tracking the states of repair of individual items, and can be costly.

<sup>16</sup>Undersecretary of Defense, DOD 7000.14-R, pp. 52–2 and 3.

**Table 5**  
**Summary of Recommendations**

Major Costs	Location in Current Exchange Price Structure	Recommended Method of Recovery
Condemnnations	Surcharge	Exchange price/standard price <ul style="list-style-type: none"> <li>• Average cost associated with individual NSNs when customer cannot affect carcass condition</li> <li>• Cost associated with specific items otherwise</li> </ul>
First destination transportation	Surcharge	Exchange price/standard price <ul style="list-style-type: none"> <li>• Average cost associated with individual NSNs</li> </ul>
COD: DLA issues & receipts		
COD: item management		
Price stabilization	Surcharge	Fee to customer commands <ul style="list-style-type: none"> <li>• If attributable to specific NSNs or specific demands, charge according to usage</li> <li>• Otherwise, arbitrarily allocate</li> </ul>
Depreciation		
Inventory maintenance		
Inflation		
COD: other inventory control point activities		
Direct materials	DRC	Exchange price <ul style="list-style-type: none"> <li>• Average repair cost for a given NSN if customer cannot affect the state of the returned carcass</li> <li>• Average cost of the specific repair otherwise</li> </ul>
Direct labor	DRC	
Utilities (repair facilities)	DRC: G&A	

Table 5—continued

Major Costs	Location in Current Exchange Price Structure	Recommended Method of Recovery
Indirect labor	DRC: production overhead	Exchange price
Schedulers		<ul style="list-style-type: none"><li>Costs associated with individual NSNs to the extent feasible</li></ul>
Planners		
Indirect material		
Equipment depreciation	DRC: production overhead	Fee to customer commands <ul style="list-style-type: none"><li>If attributable to specific NSNs or specific demands, charge according to usage</li><li>Otherwise, arbitrarily allocate</li></ul>
Base support	DRC: G&A	Fee to customer commands
HQ costs		<ul style="list-style-type: none"><li>Arbitrary allocation</li></ul>
Utilities (nonrepair related)		

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**CONCLUSIONS**

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The current structure of DLR exchange prices creates incentives for customers to take actions that are not cost-effective for the Air Force. The fact that prices are greater than the marginal costs associated with DLR transactions biases customers toward local repair, away from transacting with the working capital fund. When the cost of local repair is less than the exchange price but greater than the cost of depot-level repair, customers save O&M funds, but Air Force costs increase. In the long term, customer commands may overallocate repair resources to their wings. The fixed, average cost nature of DLR prices creates opportunities for customers to save O&M funds by altering the condition of returned carcasses so as to reduce the number of transactions with the fund. Air Force costs can increase because of duplicate repair facilities at the local level and through higher depot repair costs. Prices increase in the future to reflect higher repair costs, strengthening incentives for customers to take avoidance actions. The current structure of prices bundles fixed costs associated with repair and the costs of nonrepair services into DLR exchange prices. The reduced visibility of costs distorts customer decisionmaking and provides no incentives to reduce the cost of providing support services. Finally, the fact that recovery of costs that do not vary with the number of transactions depends on demand forecasts and the fact that prices are based on two-year-old costs work against recovery of costs, preventing the fund from breaking even each year.

To lessen these problems, we recommend implementing a two-part price structure in which costs unrelated to the rate of repair are recovered from customers separately from DLR exchange prices. Our

recommendations should increase the compatibility of DLR stock funding with Air Force support goals and should lead to a price system that will not need to be changed as support strategies change. At command and wing level, the recommended price structure should eliminate customer disincentives for initiating or supporting changes that would move repair to the depot level. The current system, for example, is biased against two-level maintenance, which the Air Force may need to use more extensively if active duty personnel reductions lead to reductions in base-level manning. Including only marginal repair costs in DLR exchange prices (thereby reducing the exchange prices of most DLRs) and charging other repair-related costs directly to commands should eliminate this bias without causing the reverse bias in favor of depot-level repair.<sup>1</sup>

At the depot, the recommendations support other initiatives intended to improve depot effectiveness. RAND has developed product-oriented “motivational metrics” to provide stronger incentives for reducing repair cycle times and costs while maintaining or increasing the quality of repair. The depot shop motivational metric includes the same pipeline inventory credit for beating the repair time standard and debit for exceeding it as our recommendation. Also, eliminating the surcharge reduces incentives for unrecorded job routing of SRUs, thereby improving data on failure rates used for developing the bill of materials (BOM). Finally, improved visibility of repair costs should lead to more efficient resource allocation decisions within the depot.

There are factors that limit the benefits that can be achieved by changing the current price system structure. One is the inaccuracy of depot cost information. As discussed in Chapter Three, many elements of the depot repair cost for a DLR are allocations from more aggregated cost measures rather than costs directly related to the repair of that DLR. Thus, it is not currently possible to accurately associate the indirect and overhead costs with the repair of each NSN.

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<sup>1</sup>That is, it should not lead to a general shift from local to depot-level repair unless it is less costly to perform these repairs at the depot level. In the absence of a depot advantage unrelated to cost—e.g., configuration control—depot repair is more attractive than local repair only when depot repair costs reflect economies of scale. Otherwise, the responsiveness of local repair plus the costs associated with depot-level repair that are not associated with local repair—transportation and pipeline inventory—will maintain the attractiveness of local repair.

Ultimately, accurate depot repair costs need to be determined through cost analyses to improve the Air Force's ability to assign indirect and overhead costs to the factors that drive them.<sup>2</sup> Similarly, customer commands need accurate information about the cost of local repair to make sound decisions about the provision of repair resources to their wings.

Restrictions on competition for repair also limit the gains from restructuring prices because the incentive effects of prices are limited when choice is limited. Wings cannot officially substitute local for depot-level repair without permission from the cognizant ALC; thus, the skewed incentives associated with the current price have smaller effects on decisions than they would if wings were free to substitute. However, if commands and wings were provided with the right information to make cost-effective support decisions from the Air Force point of view, it would be to the advantage of the Air Force to allow them more choice. Similarly, absent competition from private contractors or other repair depots, depot repair shops have less motivation to seek ways to reduce their costs and improve their rate of output.

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<sup>2</sup>Poor identification of costs with products is also a problem in the private sector—especially for organizations that produce diverse products. See Cooper (1989), pp. 77–82. Many private sector firms have turned to activity-based costing to help match costs with end products. See O'Guin (1991) and Ostrenga et al. (1992).

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**A REVIEW OF THE ECONOMICS AND ACCOUNTING  
LITERATURE ON INTERNAL TRANSFER PRICES**

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**INTERNAL MARKETS**

In response to increased pressure to innovate quickly and reduce costs, the business community has experienced an organizational transition from traditional centralized hierarchies to internal markets consisting of self-guided enterprises or profit centers. Magidson and Polcha (1992) characterize these internal markets as follows. Rather than providing budgets directly to internal selling centers, budgets are given to the operating units to purchase services or products either from internal or external suppliers. Internal suppliers have the freedom to sell their services or products to external customers as well as internal ones. Finally, high-level management retains the right to overrule any external transaction for strategic reasons.

There are many benefits associated with such a decentralized organization. Profit centers have increased flexibility to adapt to changing business environments. This operational freedom creates an innovative atmosphere that produces higher-quality services and products. The internal market also provides an increased awareness of costs and results in greater efficiencies. Finally, high-level management is able to focus on strategic decisions rather than the day-to-day operational details of the business. (See Halal, 1994.)

**ROLE OF TRANSFER PRICES**

Just as prices facilitate transactions in external markets, internal transfer prices enable profit centers to transact in internal markets. Eccles (1985) estimates that 80 percent of the *Fortune* 1,000 compa-

nies have internal transfer prices for goods. In an earlier survey, Vancil (1978) estimates that on average the amount of goods traded internally is equivalent to 10 percent of total sales or total cost of goods sold.

There is some disagreement between the economics and accounting literatures about which activities and outcomes internal transfer prices should be designed to influence. The economics literature proposes that transfer prices should be designed to lead autonomous profit centers to make decisions that maximize firm profits—that is, prices should lead centers to make decisions that the firm's executive managers would if they had full information. (See Hirshleifer, 1956.) However, the accounting literature adds a second goal for transfer prices—they should aid, rather than impede, the performance evaluation process for profit centers and their managers. (See Benke and Edwards, 1980; Eccles, 1985 and 1991; and Kaplan and Atkinson, 1989.) To the extent that profit centers are evaluated according to their return on investment and profit, transfer prices should be designed so that they do not distort profits or costs across centers, giving false impressions of performances and contributions to the corporation. Such distortions could lead center managers to make suboptimal production or investment decisions. As is discussed below, the goals of profit maximization and aiding performance evaluation can work against each other.

The transfer pricing goals of promoting optimal resource decisions and supporting performance evaluation are short-run goals. Hirshleifer (p. 184) concludes his analysis with a cautionary note about using transfer prices for strategic decisions: "When non-marginal decisions like abandoning a subsidiary are under consideration, a calculation of the incremental revenues and costs of the operation as a whole to the firm should be undertaken."<sup>1</sup>

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<sup>1</sup>Solomons (1965) recommends using linear programming to calculate shadow prices of those resources for which transfers are constrained by internal production capacity. Shadow prices, which indicate the change in total profits associated with a unit increase in production capacity, can facilitate long-run capacity decisions.



## THEORY OF OPTIMAL TRANSFER PRICES

There is a large body of research on optimal transfer prices that stems primarily from the microeconomics and accounting literatures. There are several comprehensive reviews of this work (see Eccles, 1985, and Eccles and White, 1988); therefore, we focus here on a few papers that represent the range of transfer pricing research across disciplines.

In his seminal article, Hirshleifer (1956) derives optimal transfer prices that lead autonomous profit centers to make decisions that maximize firm profits. Assuming that the operating costs of each center are independent of the level of operations in other centers (technological independence) and that additional external sales by a center do not reduce external demand for the other centers' products (demand independence), Hirshleifer demonstrates that the optimal transfer price is the marginal cost of producing the intermediate good or service. More generally, the center that produces the intermediate product should provide a schedule of marginal cost associated with different output levels so that the center that produces the end product can choose the optimal joint level of output. The only circumstance under which this optimal price equals the market price for the intermediate product is when the external market for the product is perfectly competitive. Marginal cost transfer prices provide the center that produces the end product with the information necessary to produce at the level that is optimal for the firm as a whole—the level that equates the marginal cost of production with marginal revenue.<sup>2</sup>

Benke and Edwards (1980) have similar views on constructing transfer prices. They examined the transfer pricing practices of 19 firms to find principles that other organizations could use to implement transfer pricing policies that are appropriate for their individual cir-

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<sup>2</sup>When the assumption of demand independence is relaxed, the optimal transfer price lies between the good's marginal cost and the market price. The case of technological dependence is too complex to solve, and Hirshleifer speculates that autonomy among centers may not be possible in this case.

Neither demand nor technological dependence appears to be relevant to depot-level repair for the Air Force. There is no external demand for depot-level repair, and the depots' cost functions should be largely independent of the level of wing operations.

cumstances. Their investigation led to a general rule: an internal transfer price should equal the product's standard variable cost plus the opportunity cost associated with outside sales that were lost due to internal sales. This opportunity cost is zero when there is excess production capacity or there is no reliable external price for the product. The authors specifically exclude fixed costs from transfer prices because including them in the internal price transforms them into variable costs to the purchasing center, thus distorting decisionmaking in that center. However, they suggest several ways to pay for these fixed costs without interfering with the evaluation of centers. One way is to leave them in the selling center but not include them in profit calculations. Another is to transfer them to the corporate level. A third option is to transfer them to the purchasing center through periodic charges that are unrelated to the volume of purchases.

Eccles interviewed 144 managers in 13 firms from the chemicals, electronics, heavy machinery, and machinery components industries to determine how transfer prices are implemented and managed in practice. Eccles (1985 and 1991) and Eccles and White (1988) discuss the three most common transfer pricing policies observed in the survey: mandated full-cost transfers, mandated market-based transfers, and exchange autonomy in which prices range between full cost and market.<sup>3</sup> In addition to observing diversity in policies across firms, the authors observed multiple policies even within firms corresponding to different product strategies and environments. This divergence between theory and practice—in particular, a lack of marginal cost pricing and frequent use of full-cost transfers—led to a new theory to explain transfer pricing practices.

Eccles (1985) and Eccles and White (1988) emphasize that a firm's transfer prices must be tailored to support the firm's strategy and policies. Further, prices must be flexible enough to adapt to changes

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<sup>3</sup>Eccles (1991) discusses a fourth transfer pricing policy that is used selectively for specific strategic purposes. The author observes that firms with low vertical integration and independent centers that are evaluated based on financial performance objectives sometimes use dual pricing to promote internal transfers in the presence of excess capacity in the selling center or a proprietary technology. The dual transfer pricing policy is characterized by the purchasing unit paying cost and the selling unit receiving market price for the transferred product. However, the firm must reconcile any double counting across centers.

in these. Eccles and White link the three popular transfer pricing practices to two strategic questions that any firm with an internal market must address. The first is whether the profit centers are part of a strategy of vertical integration; that is, are internal transfers mandated or are purchasing and selling centers allowed to make choices among potential internal and external exchange partners that maximize their individual outcomes. If the firm has a strategy of vertical integration, the second question is whether the firm is pursuing a strategy of vertical integration to lower the costs of intermediate products. If so, Eccles' survey indicates that the firm will implement full-cost transfer prices.<sup>4</sup> Otherwise, the firm will use market-based prices that facilitate comparisons of internal profit centers to external competitors. Eccles (1985) argues that transfer prices based on variable costs are rarely seen in practice because they hinder measurement and evaluation of profit center contributions to the company.

Eccles (1991) notes that a firm's performance evaluation policy must match its transfer pricing strategy for each to be effective. A selling center manager who is evaluated based on financial performance measures will not like transfer prices based on marginal or variable costs because the center does not earn any profit from internal sales to help offset its fixed costs. Thus, the center has low reported earnings, which leads to low morale. For centers that transact using mandated full-cost prices, evaluations should emphasize corporate performance and individual performance rather than the financial performance of centers. For centers that use mandated market-based prices, evaluations should be based on financial measures such as center profit and return on investment as well as more subjective criteria such as interdependent contributions.

Kaplan and Atkinson (1989) also acknowledge the tension between the transfer pricing goals of promoting economic decisions and enhancing performance evaluation and tie their recommendations for optimal transfer pricing policies to firm strategies and environments.

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<sup>4</sup>Two types of full-cost transfer prices are observed in practice. The first type is standard full cost, which is calculated as the expected unit cost of production for a specified period. The selling unit is responsible for any variation in its costs. The second type is actual full cost, which transfers responsibility for any variation in the selling center's costs to the purchasing center. See Eccles (1991) and Eccles and White (1988).

The authors' first three recommendations are quite similar to those discussed above. First, if a competitive market exists for the intermediate product, Kaplan and Atkinson recommend that the transfer price for the item should be set equal to the market price (less transaction costs that are avoided with internal transfers). At the other extreme, if no external market exists for the intermediate product, the transfer price that leads to the optimal level of internal transactions is the marginal cost of production. The authors also advocate that the purchasing center should pay a fixed fee to the selling center for the privilege of transacting with it at marginal cost. This fixed fee would cover the selling center's fixed costs. By assigning fixed costs in proportion to the percentage of capacity devoted to the internal purchaser, this two-part pricing scheme leads to efficient resource allocation while allowing the selling division to recover its costs and forcing the purchasing center to recognize the full cost of obtaining products from the selling center.<sup>5</sup> When an imperfectly competitive market exists for the intermediate product, Kaplan and Atkinson recommend that the managers of the purchasing and selling centers negotiate the price and terms of the transfer. This policy's success requires freedom to buy and sell externally, occasional transactions with external suppliers and buyers, and support from high-level management.

Kaplan and Atkinson's recommendations diverge from those of Eccles (1985 and 1991) and Eccles and White (1988) with respect to full-cost prices. While Kaplan and Atkinson note that such prices are often used in practice, they find no justification for them. The authors argue that full-cost prices distort economic decisionmaking by transforming the fixed costs of the selling center into variable costs for the purchasing center. These prices provide poor incentives for the selling center because they do not reward efficiency or penalize inefficiency. Full-cost prices also do not contribute to evaluating the performance of centers. And finally, inclusion of firm costs, such as G&A, that are allocated across centers may make the firm's end product less competitive (e.g., if the prices of intermediate products include a proportional markup for profit).

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<sup>5</sup>Solomons' (1965) recommendations are consistent with these of Kaplan and Atkinson.

## **ALLOCATING COSTS CORRECTLY**

Kovac and Troy (1991) discuss Bellcore's struggle to find full-cost transfer prices for support services that would encourage staff to use internal services and pay a fair price for them. Bellcore's original transfer pricing system assigned overhead costs such as G&A and non-usage-based services (e.g., records management, library services) to divisions based on headcount. As a result, the cost of labor-intensive support services such as graphics, technical publications, and secretaries were too high. This resulted in highly trained technical researchers performing these tasks for themselves or negotiating with outside vendors.

Bellcore formed a task force to look into the problems with its internal transfer prices. This group discovered that non-usage-based services and G&A services were a larger percentage of total costs for the labor-intensive support services divisions than for other divisions. Therefore, the task force set out to determine the appropriate drivers for these costs. Analysis indicated that for non-usage-based services, the appropriate driver is the percentage of technical and administrative personnel in the division. The task force also discovered that headcount drives a portion of G&A expenses (e.g., personnel, security), but that the percentage of the firm's direct and capital-related costs attributable to the division is closely related to the remainder of the expenses (e.g., legal, comptroller). Better cost allocation has led to a transfer pricing system that everyone perceives as fair and a better allocation of the technical staff's time.

## **USING CONFLICT**

Conflicts among parties can arise in any market situation, and parties to internal transactions are not immune to conflict just because they are part of the same organization. However, as Eccles and White (1988) and Halal (1994) note, conflict among profit centers does not necessarily prevent desired transactions, and it may even be encouraged by high-level management because of the information it generates.

Eccles and White note that when centers are required to transact with one another and when transfer prices are based on the full cost of the transfer (which includes fixed costs), conflict may arise from

the difficulty of allocating fixed costs. When prices are determined in advance of actual demands, the financial performance of selling centers is linked to the actual demands of buying centers. The conflict associated with the difficulty of separating financial performance of one center from another may lead center managers to monitor each other's centers, reducing the time high-level managers must spend monitoring center activities. Also, this conflict provides information to top management that would be difficult or costly to obtain otherwise, and trying to do so may provide center managers with the excuse of interference of top managers for not meeting their goals.

Halal reports that high-level management at MCI promotes conflict among its centers for slightly different reasons. When new ideas for products such as Friends & Family arise from MCI's independent business units, management tries to avoid diluting unit autonomy by imposing centralized decisions. Constructive debates among the business units over new ideas usually result in decisions that everyone can support.

## TRANSITION TO INTERNAL MARKETS

The transition to internal markets can be traumatic for organizations that have existed for years as centralized hierarchical entities. Magidson and Polcha (1992) and Halal (1994) characterize implementation plans that help minimize the short-run costs associated with the transition.

Magidson and Polcha relate the transition experience of John Charlton of Esso Petroleum Canada. Charlton suggests that prior to implementation, an organization should ensure the participation of everyone at all levels of the organization, formally introduce the concept of internal markets, and recognize that not all current employees will be happy and productive in the new environment. To continually promote implementation, he recommends that the organization create a shared vision for the new organization, invest in training for business skills necessary for the market environment, provide timely feedback on results, create a method to measure the contribution of all levels of the organization, recognize and reward

success, and develop an accounting system that can support internal transactions.<sup>6</sup>

Halal adds that it is useful to begin the transition within a small part of the organization, recruit enterprising employees to be involved in the pilot project, and make the reorganization effort the top priority.

### **TRANSFER PRICING IN THE DEPARTMENT OF DEFENSE**

Recently, many economists and accountants have become interested in the application of transfer pricing theory to the Department of Defense's implementation of stock funding.

Rogerson (1995) discusses three particularly problematic features of DLR pricing in the Air Force: (1) costs attributable to the supply system but not to repair are allocated to repair prices, (2) replacement costs are tied in to repair prices, and (3) the supply system charges the same for repairs of below-average difficulty as for more difficult ones for each type of DLR. His analysis suggests that the consequence of the first two of these features is that repair prices are too high, leading military units in many instances to avoid transacting with the supply system for DLR repairs when depot repair is actually the most economical source of repair in terms of total cost to the Air Force. Rogerson argues that the third feature induces military units to perform more of the easy repairs on base even when it is more economical for the Air Force for those repairs to be performed at the depot.

Rogerson recommends that those central logistics costs that do not vary with the rate of repair should be funded through annual charges to the major commands and/or to the Air Staff. Costs of replacing condemned items should be recovered through charges to military units based on the number of each type of DLR they use. He also recommends improving internal information systems to enable improved tracking of repair costs and, thereby, allow for repair charges based on difficulty of repair.

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<sup>6</sup>See Cooper (1989) for a discussion of how a poor cost accounting system can lead to transfer prices that are inconsistent with a firm's internal market strategy.

Trunkey and Choi (1996) discuss four reasons why they conclude that DBOF, and presumably now the working capital fund, has not yielded good decisionmaking. First, like Rogerson and others, they point out that prices do not reflect costs of providing services. Second, customers have little choice among service providers and sometimes must purchase from a sole supplier who has little incentive to produce efficiently. Third, those making decisions about location of repair are not always the ones who must pay the bills or who have the best information. An example of this problem is when location of repair is mandated rather than left to a unit's discretion. Finally, producers have little ability or incentive to reduce costs. For example, the central logistics function cannot, on its own, decide to close a depot and consolidate workload. And limited competition creates little incentive to reduce costs even if the ability were there.

Trunkey and Choi recommend solving these problems by eliminating price stabilization and excluding fixed costs and past-year losses from prices, instead recovering these funds through separate charges to customers. They also recommend increasing public/private competition and penalties for losses and rewards for gains to service suppliers. Finally, they recommend placing more decisionmaking authority in the hands of the unit purchasing the service.

Placing decisionmaking authority with the customer without correcting price distortions can result in worse outcomes. Camm and Shulman (1993) provide a case study of how a location of repair decision was influenced by Air Force DLR pricing. Faults attributed to avionics components often cannot be duplicated (CND) by test equipment. If the fault cannot be duplicated, the item is returned to stock and no further repair cost is incurred. However, the customer is charged the same price whether or not an item needs repair. Thus, the customer is overcharged for items not found to need repair. In spite of Air Force policy to repair all F-16 avionics at depot level, Air Combat Command (ACC) chose to maintain resources to screen for CNDs at F-16 bases rather than pay overcharges associated with DLR prices for these items. Camm and Shulman suggest that the inability of ACC wing commanders to trade off personnel and other resources also contributed to this decision. The authors' analysis shows that it is less costly to the Air Force to consolidate F-16 avionics component CND screening at the depot. Thus, the pricing strategy and con-



straints on decisionmaking contributed to an inconsistency between ACC's financial interests and those of the Air Force.

The General Accounting Office (GAO, 1994) also recommends that fund prices should reflect actual costs of providing goods and services. Recovering prior-year losses through increased current prices "distorts the Fund's actual results of operations in a given year, diminishes the incentive for the Fund to operate efficiently, and makes it difficult to evaluate and monitor the Fund's status."<sup>7</sup> The GAO recommends that prior-year losses be recovered through a separate appropriation.

The GAO points out that prices are based on data and assumptions from as early as two years before the prices go into effect, and, therefore, it would expect differences between estimated and actual outcomes. However, the GAO attributes the large differences between revenues and actual costs (as of 1994) to systemic problems, including unrealistic productivity assumptions. GAO also discusses the absence of reliable financial data and recommends that DoD "pursue short-term efforts to improve the quality of the information used to prepare the Fund's financial reports."<sup>8</sup>

Glass (1994), in a brief issue paper, considers the long-run consequences of current DLR pricing distortions. He suggests that a pricing system that induces customers to avoid transacting with the repair depots in peacetime may be problematic if the repair depots are to provide responsive wartime support. Glass lists four alternatives for fund pricing policy. First, as more repair migrates to the local level, allow prices to rise (because fixed costs must be covered by a smaller sales volume). This would ultimately put pressure on the depots to reduce their fixed costs but would yield uneconomic dependence on local repair. Second, constrain customers from making uneconomic choices.<sup>9</sup> This alternative removes the ability of the price system to provide information and choice to the customer and presumes that the central authority has better information than

<sup>7</sup>GAO (1994), p. 7.

<sup>8</sup>Ibid., p. 16.

<sup>9</sup>In fact, the Air Force has attempted this by requiring that an alternative source of repair be less costly than the depot repair cost. See the discussion in Chapter Four.

the customer. Third, as others have recommended, eliminate the fixed costs from the calculation of prices and recover these costs in some other way. Fourth, allow customers complete freedom to choose their sources of repair. This alternative, given current pricing strategies, would almost surely yield a reduction in depot wartime capacity.

Melese (forthcoming) focuses on the behavior of the depot repair shops that transact with DBOF (now the working capital fund). He argues that, in the absence of competition, current pricing and pricing approaches recommended by others offer insufficient incentives for reducing cost of depot repair. He recommends that the surplus of revenues over costs resulting from cost reductions be shared with depot shops over multiyear periods to provide incentives "to foster efficiency and productivity improvements." The multiyear approach is required to induce the depot to engage in cost-saving capital investments. The ability to attribute cost reductions to specific organizational changes or investments is a central requirement of this recommendation.

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**DERIVATION OF PRICING RECOMMENDATIONS**

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In this appendix, we derive the pricing recommendations found in Chapter Five. Through five cases, we illustrate the effects of various pricing schemes on the behavior of commands and wings and the cost of that behavior to the Air Force. These cases were chosen to capture many of the characteristics of repair activities within the Air Force depot maintenance system. In the first case, the DLR has only one type of repair that can be performed at either the local level or at the depot. In the second, the DLR may need an easy or a difficult repair. The easy repair can be done at the local level; however, the difficult repair can be done only at the depot level. In the third case, the DLR is an avionics box that can be screened at the local level. The box contains only one electronic card, so cannibalization is not possible. In the fourth case, the avionics box contains two cards; therefore, wings can alter the condition of the returned carcasses through cannibalization. In the fifth case, the wing can affect the probability that a mechanical item is condemned. Effort to reduce the condemnation rate is costly to the wing. Table B.1 summarizes the main attributes of these cases.

In each case, we first examine the costs of depot-level repair and local repair to the Air Force. Next we examine the costs of the two sources of repair to customer commands and wings based on the current structure of DLR prices. We then demonstrate that the current price structure distorts customer incentives toward local repair (or, in case 5, a higher probability of condemnation). Finally, we examine customer incentives based on the multipart pricing scheme for DLRs recommended in Chapter Five. In each case, the recom-

**Table B.1**  
**Summary of Illustrative Cases**

Case	Condemnations	No. of Different Repair Actions	Possible Wing Actions Affecting Repairs at Depot
1	No	1	None
2	No	2	Sorting
3	No	2	Sorting
4	No	3	Cannibalization
5	Yes	2	Change condemnation rate

mended pricing scheme leads customers to take actions that are cost-effective for the Air Force.

At the end of Appendix B, we derive the cost of exchanging an un-serviceable for a serviceable DLR when the item is in excess supply.

### CASE 1

In case 1, the reparable is an item that has only one type of repair. When the item does not perform correctly in the aircraft, it is removed at the flight line. The repair can take place either locally (at the wing level) or at the depot. We assume that the item is never condemned. For simplicity, we assume that the command has only one wing and that the command decides whether or not to provide repair resources to the wing no more than once a year. Thus, costs are calculated on a yearly basis.

### Air Force View of Costs

If the wing does not have its own repair capability, the Air Force expects the annual repair cost for this NSN attributable to the wing to be  $F_d + Nr_d$ ,

where  $F_d$  is the yearly fixed cost associated with having depot-level repair for this NSN attributable to the wing;<sup>1</sup>

<sup>1</sup>The wing's portion of depot-level fixed costs can rise or fall as the total number of customers decreases or increases. Also,  $F_d$  may be small if not many fixed costs can

- $N$  is the expected number of items that the wing will have to remove from its aircraft during the year; and
- $r_d$  is the marginal cost of depot repair (to include direct labor, direct material, pipeline inventory, transportation, etc.).

This cost includes the wing's share of the fixed cost of the depot repair capability and the expected marginal cost of repairing the unserviceables exchanged by the wing.

If the command establishes (or maintains) a wing-level repair capability, the wing will repair each unserviceable item and have no dealings with supply for this DLR as long as the wing's marginal cost of repair is less than the DLR exchange price. In this case, the Air Force anticipates that the command and wing will incur costs for the year equal to  $F_w + Nr_w$ ,

where  $F_w$  is the yearly fixed cost associated with having wing-level repair; and

- $r_w$  is the marginal cost of repair at the wing (to include direct material, manpower, etc.).<sup>2</sup>

This cost includes the fixed cost of having the repair capability at the wing, and the expected marginal cost of repairing unserviceable units at the wing. We assume that the depot incurs no repair cost for this DLR that can be attributed to the wing.

Comparing the two costs, we find that the total cost to the Air Force for the year is lower with local repair than without when

$$F_w + Nr_w < F_d + Nr_d.$$

be allocated to specific NSNs. We assume that  $F_d$  is not proportional to demand for the NSN. However, adding this complication would not change the essential nature of the conclusions of the analysis.

<sup>2</sup>For organic repair, we include manpower costs in marginal rather than fixed costs, despite manpower strengths being fixed in any fiscal year, because there are alternative uses for manpower. The marginal cost of local contract repair is the price charged to the wing.

This holds when the expected total cost of repairing these items locally is less than the expected total cost associated with depot repair.<sup>3</sup>

### Customer Decisionmaking Under Current DLR Price Structure

Under the existing pricing structure, there is a single exchange price,  $P$ , for each item. If the wing does not have its own repair capability, the command expects the wing to pay  $NP$  because it must exchange each unserviceable item. If instead the command provides the wing with its own repair capability, the command sees costs equal to  $F_w + Nr_w$  because it pays all the costs of local repair (directly through equipment and manpower and indirectly through the wing's maintenance budget). The command will thus find that it is less costly for the wing to have its own repair capability when

$$F_w + Nr_w < NP.$$

This occurs when the expected cost associated with repair at the wing is less than the expected payments for depot-level repair.

This fixed pricing scheme will give commands excessive incentives to provide wings with their own repair capability when  $P > r_d + F_d/N$ , as is the case for most items under the current DLR pricing scheme. However, when there is uncertainty about the exact value of  $N$ , the command may have an excessive incentive to repair locally even if  $P = r_d + F_d/N$ .

If the realized number of repairs,  $N'$ , exceeds the expected value,  $N$ , the command will pay too much to the depot; that is, the depot will overrecover its costs by  $(N' - N)(F_d/N)$ , where  $N' - N$  is the amount by which the actual number of repairs exceeds the expected

<sup>3</sup>We recognize that there are strategic non-cost-related concerns associated with level-of-repair decisions. This aspect of the decision could be easily addressed in the following way. Let  $V_w$  denote the value associated with local repair (in comparison to depot repair). For example, repair capability may reduce the risk of having planes that are not mission-capable because of supply backorders. This value is subtracted from the cost associated with local repair when comparing the cost of level-of-repair alternatives. For the rest of Appendix B, we will assume that level-of-repair decisions are based solely on costs.

number. If the realized number of repairs is less than expected, the command will pay too little and the depot will underrecover its costs. If the consequences of overpayment are serious, the command may be unwilling to take a chance of overpaying the depot and decide to provide the wing with its own repair equipment anyway. (For example, the wing may not accomplish its flying program if  $N'$  exceeds  $N$  and will save O&M funds if  $N'$  is less than  $N$ . In most instances, the penalty for not accomplishing the flying program will be greater than the benefit from achieving financial savings, so the command will prefer to provide wings with their own repair capability.)

### Customer Decisionmaking Under Two-Part Pricing Structure

Now suppose that Air Force implements a two-part price structure for DLRs. The command must specify prior to the beginning of the year whether or not the wing will be sending unserviceable items of a given type to the depot. If it will be doing so (i.e., the command does not provide the wing with its own repair capability), the command is charged the yearly fee  $F_d$  for the yearly fixed costs of depot repair attributable to the wing. When the wing exchanges an unserviceable item for a serviceable one, it pays only the additional expenses incurred by the fund resulting from that transaction. That is, the wing is charged an exchange price  $P = r_d$ . If the wing will be repairing its own unserviceables of this type of item, the command pays nothing for depot-level repair, and the wing avoids paying the exchange price.

Under the new price structure, the command still expects itself and the wing to incur costs during the year equal to  $F_w + Nr_w$  if the wing has its own repair equipment. However, if it does not provide equipment to the wing, the command now expects total cost to equal  $F_d + Nr_d$ , which is the expected cost incurred by the fund for that item on behalf of the wing. Therefore, under the two-part pricing scheme, the command will want to provide the wing with its own screening capability only when

$$F_w + Nr_w < F_d + Nr_d.$$

This means that when it is less expensive from the Air Force point of view to send all items that fail directly to the depot for repair, the command will have no financial incentive to maintain repair capability at the wing level. Conversely, when the Air Force benefits from local repair, the command will want to provide the capability.

We will now compare the ability of the alternative price structures to recover all costs associated with depot-level repair of an item. With a fixed single exchange price, total costs are best recovered by setting the price equal to the average cost of repair,  $P = r_d + F_d/N$  (based on the expected level of demand). However, as noted above, costs will be over- or underrecovered if the realized level of demand differs from the estimate used to set the price. In contrast, costs are always recovered under the two-part price scheme. The fixed costs are paid up front, and the marginal cost of each repair is recovered as the repairs are performed.<sup>4</sup>

## CASE 2

In case 2, the reparable item has two types of repairs: easy and difficult. The item might be a mechanical item that is out of alignment (easy repair) or have worn-down parts (difficult repair). The difficult repair can be performed only at the depot, but the easy repair can be made at the wing as well as at the depot. There are no condemnations.

If the wing does not have its own repair capability, each unserviceable item is exchanged for a serviceable one, and the wing pays the exchange price. If the wing has its own repair capability, it will examine each unserviceable to see if the failure was caused by the problem that is easy to fix. If so, the wing repairs it locally (as long as the marginal cost of local repair is less than the exchange price). If the item requires the difficult repair, the wing exchanges it for a serviceable item and pays the exchange price.

<sup>4</sup>Depot labor is quasi-fixed even though it is included in the marginal cost of repair. Thus, realizations of demand that differ from the predicted level will lead to a mismatch between revenues and costs under either of the alternative price structures. Because the two-part price structure is designed to capture fixed costs exactly, the discrepancy between costs and revenues will be less under this structure than under the fixed single exchange price.



As in the preceding case, costs are calculated on a yearly basis.

### Air Force View of Costs

If the wing does not have its own repair equipment, the Air Force anticipates incurring the following cost annually:

$$F_{1d} + N(1 - p)r_{1d} + F_{2d} + Npr_{2d},$$

where  $F_{1d}$  is the wing's share of the yearly fixed cost associated with having depot-level capability for the easy repair;

$F_{2d}$  is the wing's share of the yearly fixed cost associated with having depot-level capability for the difficult repair;<sup>5</sup>

$r_{1d}$  is the marginal cost of performing the easy repair at the depot;

$r_{2d}$  is the marginal cost of performing the difficult repair at the depot;

$N$  is the expected number of items that the wing will have to remove from its aircraft during the year; and

$p$  is the probability that a broken item will need the more difficult repair. This probability is assumed to be unaffected by the wing's actions.

The annual cost to the Air Force includes the wing's share of the cost of the repair capability at the depot and the expected cost of repairing each unserviceable unit from the wing.

If the command decides to supply the wing with its own repair capability, the command must notify the depot that the wing will not be sending any of the easy repairs during the year. In this case, the Air Force anticipates incurring costs for the year equal to

<sup>5</sup>For some items, the capability to perform the difficult repair is sufficient to perform the easy repair. Thus, there would be a single fixed cost associated with any degree of depot repair.

$$F_{1w} + N(1 - p)r_{1w} + F_{2d} + Npr_{2d},$$

where  $F_{1w}$  is the yearly fixed cost associated with having wing-level capability for the easy repair; and

$r_{1w}$  is the marginal cost of the easy repair at the wing.

The Air Force's total costs include the cost of having the capability for the easy repair at the wing and the capability for the difficult repair at the depot, the expected marginal cost of performing easy repairs at the wing, and the expected marginal cost incurred by the depot for the items with difficult repairs that the wing exchanges.

Comparing the two costs, we find that the total cost to the Air Force for the year is lower with local repair than without when

$$F_{1w} + N(1 - p)r_{1w} < F_{1d} + N(1 - p)r_{1d}.$$

This holds when the expected cost of performing the easy repair at the wing is less than the expected cost at the depot.

### Customer Decisionmaking Under Current DLR Price Structure

Suppose that the exchange price for an unserviceable is  $P$ , regardless of the repair needed. If the wing has its own repair capability, the command expects the following costs during the year:

$$F_{1w} + N(1 - p)r_{1w} + NpP.$$

The command incurs a fixed cost associated with the local capability. The wing incurs a marginal cost of repair for each item that requires only the easy repair, and it pays the exchange price for each item that requires the difficult repair.

If the wing does not have its own repair capability, the command expects the wing to pay  $NP$  during the year because it must exchange each unserviceable item. The command will thus find that it is cheaper to provide the wing with its own repair capability when

$$F_{1w} + N(1-p)r_{1w} < N(1-p)P.$$

This occurs when the expected cost associated with the easy repair at the wing is less than the expected savings from not exchanging items that need only the easy repair. Thus, the command will provide the wing with its own repair capability for the easy repair when  $P > F_{1w}/N(1-p) + r_{1w}$ .

This fixed pricing scheme will give commands excessive incentives to provide wings with the capability to perform easy repairs when  $P > F_{1d}/N(1-p) + r_{1d}$ , that is, when the DLR price is greater than the average cost of performing an easy repair at the depot (based on the expected number of repairs). If  $P = F_{1d}/N(1-p) + r_{1d}$ , the command will provide the equipment to the wing only when it is the least-cost way to provide the easy repair from the point of view of the Air Force. Note, however, that the depot would not recover its costs if it charged this price. If the forecast of the number of easy repairs is correct, the depot would recover these costs, but it would lose money on the difficult repairs.

### Customer Decisionmaking Under Two-Part Pricing Structure

Now suppose that the Air Force implements a two-part pricing scheme for DLRs. If the command provides repair capability to the wing, it notifies the depot that the wing will not be sending any easy repairs and is charged a yearly fee of  $F_{2d}$  for the wing's share of the yearly fixed costs associated with difficult repair at the depot level. If the command does not provide wing-level repair capability, the command pays a yearly fee of  $F_{1d} + F_{2d}$ . When the wing exchanges an unserviceable for a serviceable item (regardless of whether it has its own repair capability), it pays only the additional expenses incurred by the depot resulting from that transaction. That is, if the item requires only the easy repair, the wing is charged  $r_{1d}$ . If it requires the difficult repair, the wing is charged  $r_{2d}$ .

The command now expects itself and the wing to incur the following costs during the year if the wing has its own repair resources:

$$F_{1w} + N(1-p)r_{1w} + F_{2d} + Npr_{2d}.$$

The command pays for the repair capability at the wing and the wing's share of the cost of repair capability at the depot. The wing pays the marginal cost of easy repair locally, and the marginal cost of difficult repair at the depot (the wing sends in only items that need the difficult repair). If it does not provide equipment to the wing, the command expects total cost to equal

$$F_{1d} + N(1 - p)r_{1d} + F_{2d} + Npr_{2d},$$

which is the expected cost incurred by the depot on behalf of that wing.

Therefore, under the two-part pricing scheme, the command will want to provide the wing with its own screening capability only when

$$F_{1w} + N(1 - p)r_{1w} < F_{1d} + N(1 - p)r_{1d}.$$

Under this pricing scheme, when it is less expensive from the Air Force point of view to send all of the unserviceables to the depot for repair, the command will have no financial incentive to maintain repair capability at the wing level. Conversely, when the Air Force benefits from local repair, the command will want to provide the capability. Finally, the customer pays the total cost that it imposes upon the depot maintenance system.

### CASE 3

Case 3 is much like case 2. The DLR is an avionics LRU containing one SRU (an electronic card). When a failure is believed to have occurred, the avionics box is removed at the flight line; however, a removal does not necessarily mean that the electronic card needs to be repaired. The repair process consists of two steps. First, the box is screened to see whether the failure can be duplicated, implying that the card needs to be repaired. If the box fails the screen, the card is repaired and the box is returned to supply. If the failure cannot be duplicated, then the box is immediately returned to supply. Repair of electronic cards takes place only at the depot; however, wings can screen avionics boxes if they have the appropriate personnel and equipment. When a wing has this capability, it avoids exchanging

boxes for which the failure cannot be duplicated. We assume that there are no condemnations.

Suppose that an avionics box has been removed at the flight line because of an indication of failure. If the wing does not have its own screening equipment and personnel, it pays the exchange price and exchanges the unserviceable box for a serviceable one. If the wing has its own screening capability, it screens the unserviceable box to determine whether it is a false failure. If the box passes the screen, the wing keeps it. If the box fails, indicating that the electronic card is broken, the wing pays the exchange price and exchanges the box for a serviceable one.

### Air Force View of Costs

If the command does not provide the wing with its own screening capability, the expected cost to the Air Force during the year is

$$F_d + Ns_d + Npr_d,$$

where  $F_d$  is the wing's share of the yearly fixed cost associated with having depot-level screening and repair;

$N$  is the expected number of avionics boxes that the wing will have to remove from its aircraft during the year;

$s_d$  is the marginal cost of screening an additional box at the depot;

$r_d$  is the true marginal cost of repairing one electronic card at the depot; and

$p$  is the probability that the card in an avionics box will fail during the screening process given that it had problems at the flight line. This probability is assumed to be unaffected by the wing's actions.

The Air Force incurs the wing's proportion of the depot's fixed cost as well as the expected cost associated with screening and repairing the unserviceable boxes.

If the command provides the wing with its own screening equipment, the expected cost to the Air Force is represented by

$$F_w + Ns_w + F_d + Np(s_d + r_d),$$

where  $F_w$  is the yearly fixed cost associated with having wing-level screening; and

$s_w$  is the marginal cost of screening an additional box at the wing.

The wing screens each box that is removed at the flight line. It keeps the box when it cannot duplicate the failure, and it exchanges the box when the card is bad.

The Air Force prefers the wing to have screening equipment when

$$F_w + Ns_w < N(1 - p)s_d,$$

which holds when the expected additional cost incurred from screening at the wing is less than the expected cost of screening unserviceable boxes at the depot (the total number of broken electronic cards remains the same).

### Customer Decisionmaking Under Current DLR Price Structure

Suppose that the wing is charged a fixed price,  $P$ , each time it exchanges an unserviceable box for a serviceable one. If the wing does not have the capability to screen boxes, the command expects the wing to incur a yearly cost of  $NP$ .

If the command provides the screening capability to the wing, it anticipates that its costs combined with those of the wing will equal

$$F_w + Ns_w + NpP.$$

The wing screens each box that is removed at the flight line prior to exchanging it and only exchanges those boxes with broken cards.

With a fixed price, the command will desire to provide the wing with its own screening capability when

$$F_w + Ns_w < N(1 - p)P,$$

which occurs when the expected cost of the local screening capability is less than the expected cost of returning serviceable boxes to the depot. However, the Air Force as a whole saves only  $N(1 - p)s_d$ , so the command will have excessive incentives (from the Air Force point of view) to provide the wing with its own screening capability when  $P > s_d$ . This inequality holds under current DLR prices. Exchange price  $P = s_d$  aligns command and Air Force incentives, but this price leads to an underrecovery of the fixed cost of having the capability at the depot and the cost of repairing broken electronic cards.

### Customer Decisionmaking Under Two-Part Pricing Structure

Now suppose that a two-part price system is put into place. The command pays a fee,  $F_d$ , to cover the wing's portion of the fixed cost of the repair capability at the depot. Each time the wing exchanges an unserviceable avionics box for a serviceable one, the wing is charged an exchange price that reflects the cost of the depot repair services required to restore the box to serviceable condition. If the wing turns in a box that passes the screening process at the depot, the wing is charged  $s_d$ . If the wing turns in a box with a broken card, the wing is charged  $s_d + r_d$ .

Although the Air Force's view of costs has not changed, the command views the cost of level-of-repair decisions differently under this price scheme from that under the fixed price scheme. When the wing must send all of its boxes to the depot because it does not have its own screening capability, the command expects costs equal to

$$F_d + N(1 - p)s_d + Np(s_d + r_d) \text{ or } F_d + Ns_d + Npr_d.$$

When the wing has its own screening capability, the expected cost equals

$$F_w + Ns_w + F_d + Np(s_d + r_d).$$

These two expressions reflect the exact expected cost to the Air Force of each level-of-repair alternative. Thus, the command prefers to provide the wing with its own screening capability only when it is cost-effective for the Air Force, that is, when

$$F_w + Ns_w < N(1 - p)s_d,$$

which aligns command and Air Force incentives.

Through multipart pricing that varies according to the condition of the item, the Air Force provides total visibility of costs to the command. The command finds that it is cheaper for the wing to screen prior to giving a box to supply only when the Air Force saves money through local screening. Alternatively, if there are true economies of scale associated with screening at the depot, the command will recognize them.

#### CASE 4

Case 4 is much like case 3 except that each avionics box now contains two electronic cards, implying that cannibalization is possible. For simplicity, we assume that the cards are interchangeable; however, the results of the analysis are identical when they are not interchangeable. We are concerned only with a two-day period. At the end of the second day, the wing must not have any aircraft that cannot be flown because it needs an avionics box (as long as the wing supply contains serviceable ones), and the wing must not be holding an unserviceable box. There is no discounting.

Assume that an avionics box has been removed at the flight line because of an indication of failure. If the wing does not have its own screening equipment and personnel, it pays the exchange price and exchanges the unserviceable box for a serviceable one immediately. If the wing has screening capability, it screens the unserviceable box to determine how many electronic cards (if any) need to be repaired. If the box passes the screen, the wing keeps it. If both cards are broken, the wing pays the exchange price and exchanges the box for a serviceable one. If the box has only one broken card, the wing im-



mediately draws a serviceable box from supply; however, it keeps the unserviceable one until the next day on the chance that another box will be removed and the broken cards can be consolidated. If no box is removed from another plane the next day, the wing returns the unserviceable box to supply. If another box is removed and it has one broken card, the cards are consolidated (a second serviceable box is not purchased), and the box with two broken cards is returned to supply. We refer to this as cannibalization. Assume that as long as the wing turns in a carcass before the end of the second day, it is charged the exchange price, rather than the standard price, for the serviceable box.

### Air Force View of Costs

Suppose that an avionics box has just been removed at the flight line. If the wing does not have its own screening capability, the expected two-day cost to the Air Force is

$$F_d + s_d + 2p(1-p)r_d + p^2(2r_d) + \theta s_d + \theta(2p(1-p)r_d + p^2(2r_d)),$$

where  $F_d$  is the wing's share of the two-day fixed cost associated with having depot-level screening and repair;

$s_d$  is the marginal cost of screening an additional box at the depot;

$p$  is the probability that a card in an electronic box will fail during the screening process given that the box had problems at the flight line (we assume that cards fail independently of one another and that the wing cannot affect this probability);

$r_d$  is the marginal cost of repairing one electronic card at the depot; and

$\theta$  is the probability that a second box will have problems within a day, given that one box has already been removed from an aircraft.

The Air Force incurs the wing's proportion of the depot's fixed cost as well as the expected cost associated with screening and repairing the unserviceable box(es) at the depot.

If the command provides the wing with its own screening equipment, the expected cost to the Air Force is represented by

$$\begin{aligned}
 & F_w + F_d + (1 - p)^2 \left( s_w + \theta \left( s_w + 2p(1 - p)(s_d + r_d) + p^2(s_d + 2r_d) \right) \right) \\
 & + 2p(1 - p) \left[ \left( s_w + I + (1 - \theta)(s_d + r_d) \right. \right. \\
 & \quad \left. \left. + \theta s_w + (1 - p)^2(s_d + r_d) + 2p(1 - p)(s_d + 2r_d) \right. \right. \\
 & \quad \left. \left. + p^2(s_d + r_d + s_d + 2r_d) \right) \right] \\
 & + p^2 \left( s_w + s_d + 2r_d + \theta \left( s_w + 2p(1 - p)(s_d + r_d) + p^2(s_d + 2r_d) \right) \right),
 \end{aligned} \tag{1}$$

where  $F_w$  is the two-day fixed cost associated with having wing-level screening;

$s_w$  is the marginal cost of screening an additional box at the wing; and

$I$  is the pipeline inventory cost associated with the day that the wing keeps a box with one bad card in hope of cannibalizing. The pipeline inventory cost of one LRU day is approximately equal to  $(1/365) * (i + d) * \text{FAC}$ , where  $i$  is the yearly interest rate and  $d$  is the yearly depreciation rate.

The wing screens the box before deciding what to do with it. The third term in line 1 of Expression (1) shows the expected cost when the wing cannot duplicate the failure [which occurs with probability  $(1 - p)^2$ ] and thus keeps the box. In this case, the Air Force incurs the cost of screening the box at the wing and the expected cost of wing screening and depot repair associated with a second box that fails with probability  $\theta$ . Line 5 of Expression (1) shows the expected cost when the wing immediately exchanges the box because screening indicates that it contains two bad cards (probability  $p^2$ ). Here, the Air Force incurs the cost of screening the box at the wing, the cost of

screening the box and repairing the two cards at the depot, and the expected cost associated with a second box that may fail.

Lines 2–4 of Expression (1) show the expected cost when there is one bad card [probability  $2p(1-p)$ ]. In this case, there is a chance of cannibalization (if another box comes in with one bad card). Thus, the wing holds onto the box in case another one fails. The Air Force incurs the cost of screening this box at the wing, the pipeline inventory cost associated with the wing's decision to hold onto the box, the cost of depot repair for this box if another box does not fail (probability  $1-\theta$ ), and the expected cost of wing screening and depot repair if another box does fail (probability  $\theta$ ). If another box fails, then the Air Force incurs the cost of screening it at the wing. If the wing cannot duplicate the failure for the second box [probability  $(1-p)^2$ ], the Air Force incurs the cost of depot repair for the first box. If the second box has only one bad card [probability  $2p(1-p)$ ], the wing cannibalizes and sends only one box that contains two bad cards to the depot. If the second box contains two bad cards (probability  $p^2$ ), the wing sends both boxes to the depot, and the Air Force incurs the costs of repairing both at the depot.

The Air Force prefers for the wing to have screening equipment and to cannibalize when

$$F_w + I2p(1-p) + s_w + \theta s_w < (1-p)^2 s_d + \theta(1-p)^2 s_d + \theta(2p(1-p))^2 s_d.$$

The left-hand side of this expression is the costs associated with wing screening. The right-hand side of this expression is the depot costs avoided through wing screening. Depot costs are avoided because the wing sends fewer boxes to the depot when it screens and cannibalizes. Thus, the Air Force prefers for the wing to have its own screening capability when the costs avoided at the depot exceed those incurred at the wing.

### Customer Decisionmaking Under Current DLR Price Structure

Suppose that the wing is charged a fixed price,  $P$ , each time it exchanges an unserviceable box for a serviceable one. If the wing does not have the capability to screen boxes, the command expects the

wing to incur the following cost during the two day period:  $P + \theta P$ . This is the expected cost associated with the one unserviceable avionics box today and a possible box tomorrow.

If the command provides the screening capability to the wing, it anticipates that its costs combined with those of the wing will equal

$$\begin{aligned} & F_w + (1-p)^2 \left( s_w + \theta(s_w + 2p(1-p)P + p^2 P) \right) \\ & + 2p(1-p) \left( s_w + (1-\theta)P \right. \\ & \quad \left. + \theta(s_w + (1-p)^2 P + 2p(1-p)P + p^2 2P) \right) \\ & + p^2 \left( s_w + P + \theta(s_w + 2p(1-p)P + p^2 P) \right). \end{aligned}$$

With this fixed price, the command will desire to provide the wing with its own screening capability when

$$F_w + s_w + \theta s_w < (1-p)^2 P + \theta(1-p)^2 P + \theta(2p(1-p))^2 P,$$

which occurs when the expected cost to the command of the local screening capability is less than the expected cost of replacing boxes that wing screening would identify as serviceable through the supply system.

Under the current DLR pricing scheme,  $P > s_d$ , and the command does not pay the increased pipeline inventory cost that the wing imposes upon the Air Force by holding a box for one day in an attempt to cannibalize. Hence, as in case 3, the command may provide screening capability to the wing even though it is not cost-effective from the Air Force's point of view.

### Customer Decisionmaking Under Two-Part Pricing Structure

Now suppose that a two-part price system is put into place. The command is charged the wing's portion of the fixed cost of the repair capability at the depot,  $F_d$ . Also, the wing is charged exchange prices that depend on the state of repair of the item as well as the length of time between drawing a serviceable box from supply and turning in the unserviceable one. If the wing turns in a box when it requests a

new one, the exchange price equals  $s_d$  if neither card is broken,  $s_d + r_d$  if one card is broken, or  $s_d + 2r_d$  if both cards are broken. If the wing requests a serviceable box today without simultaneously turning in an unserviceable one, the wing pays an additional cost,  $I$ , for holding the first avionics box.

Although the Air Force's view of costs has not changed, the command views the cost of level-of-repair decisions differently under this price scheme from that under the current one. When the wing sends all of its boxes to the depot, the command expects costs equal to

$$F_d + s_d + 2p(1-p)r_d + p^2(2r_d) + \theta s_d + \theta(2p(1-p)r_d + p^2(2r_d)). \quad (2)$$

When the wing has its own screening capability, the expected cost equals the cost in Expression (1) above. Expressions (1) and (2) reflect the exact expected cost to the Air Force of each level-of-repair alternative.

Through multipart pricing that varies according to the state of repair, the Air Force provides the command total visibility of costs. The command provides screening capability to the wing only if it is cost-effective for the Air Force. Alternatively, when there are true economies of scale associated with screening at the depot, the command will recognize those.

## CASE 5

The reparable in case 5 is an item that is either repaired through a single repair process or condemned and replaced. (This analysis is generalizable to allow for varying degrees of repairs.) The wing cannot repair the item, but it can affect the probability that the item must be condemned through actions such as cannibalization and/or prolonged use that also reduce the total number of items that must be exchanged during the year. For example, the DLR might be a mechanical item that is repaired if not worn beyond a particular tolerance but must be replaced otherwise.

At the beginning of the fiscal year, the wing establishes maintenance policies that determine  $\lambda$ , the condemnation rate of the item. Assume that  $\lambda$  can take on only two values,  $\lambda \in \{\lambda_L, \lambda_H\}$ , where

$\lambda_L < \lambda_H$ . Let  $N(\lambda)$  be the expected number of items that the wing will have to remove from its equipment during the year. The function is decreasing in the condemnation rate  $\lambda$ ,  $N(\lambda_H) < N(\lambda_L)$ .

### Air Force View of Costs

Given a level of effort at the wing associated with condemnation rate  $\lambda$ , the expected total cost to the Air Force for the year is

$$F_d + N(\lambda)(\lambda FAC + (1 - \lambda)r_d),$$

where  $F_d$  is the wing's share of the annual fixed cost associated with having depot-level repair;<sup>6</sup>

$\lambda$  is the probability that the item must be condemned, which is a function of the wing's actions;

$FAC$  is the expected cost of replacing a condemned item; and

$r_d$  is the marginal cost of repairing the item at the depot.

The Air Force wants the wing to behave in a way that minimizes the expected total cost, that is, choose  $\lambda \in \{\lambda_L, \lambda_H\}$  to minimize

$$F_d + N(\lambda)(\lambda FAC + (1 - \lambda)r_d).$$

The Air Force prefers  $\lambda_L$  (the lower condemnation rate) when

$$F_d + N(\lambda_L)(\lambda_L FAC + (1 - \lambda_L)r_d) < F_d + N(\lambda_H)(\lambda_H FAC + (1 - \lambda_H)r_d),$$

or

$$\frac{N(\lambda_L)}{N(\lambda_H)} < \frac{\lambda_H FAC + (1 - \lambda_H)r_d}{\lambda_L FAC + (1 - \lambda_L)r_d}.$$

<sup>6</sup>There are many ways to allocate fixed costs. We assume that the allocation here is unrelated to a wing's demand,  $N(\lambda)$ .

Loosely speaking, this expression is true when the increase in the weighted repair/replacement cost resulting from the higher condemnation rate outweighs the savings from sending fewer items to the depot. Similarly, the Air Force prefers  $\lambda_H$  (the higher condemnation rate) when

$$\frac{N(\lambda_L)}{N(\lambda_H)} > \frac{\lambda_H FAC + (1 - \lambda_H)r_d}{\lambda_L FAC + (1 - \lambda_L)r_d}.$$

Thus the optimal choice of  $\lambda$  from the Air Force's point of view depends on the functional form of  $N(\lambda)$  and the values of  $FAC$ ,  $r_d$ ,  $\lambda_H$ , and  $\lambda_L$ .

As an example, suppose that

$$\begin{aligned} FAC &= 40 \\ r_d &= 4 \\ \lambda_L &= .25 \\ \lambda_H &= .75 \\ N(\lambda_L) &= 50 \\ N(\lambda_H) &= 25. \end{aligned}$$

Then,

$$\frac{N(\lambda_L)}{N(\lambda_H)} = 2$$

(i.e., items must be removed twice as often to achieve the lower condemnation rate) and

$$\frac{\lambda_H FAC + (1 - \lambda_H)r_d}{\lambda_L FAC + (1 - \lambda_L)r_d} = 31/13,$$

which is approximately equal to 2.4. Thus, total cost to the Air Force is minimized when  $\lambda = \lambda_L$ . However, if instead  $N(\lambda_H) = 20$ , then the inequality is reversed, and the Air Force prefers  $\lambda = \lambda_H$ .

### Customer Decisionmaking Under Current DLR Price Structure

We now propose two pricing schemes and examine the effects of each on the wing's choice of condemnation rate  $\lambda$ . First, suppose that the wing is charged a fixed exchange price,  $P$ , each time it exchanges an unserviceable item for a serviceable one. The wing expects to incur costs during the year equal to  $N(\lambda)P$ . Because the exchange price it pays is independent of the condition of the unserviceable unit, choosing  $\lambda = \lambda_H$  always minimizes the wing's costs because it exchanges fewer items. Each unserviceable unit that it exchanges has the higher probability of being condemned. Note that this choice of  $\lambda$  is independent of the fixed exchange price charged,  $P$ . This implies that when

$$\frac{N(\lambda_L)}{N(\lambda_H)} < \frac{\lambda_H FAC + (1 - \lambda_H)r_d}{\lambda_L FAC + (1 - \lambda_L)r_d}$$

(so that the Air Force prefers  $\lambda_L$ ), total repair costs to the Air Force will not be minimized because the wing chooses the higher probability of condemnation. For the example above, total variable costs for the two choices of probabilities of condemnation are

$$\begin{aligned} N(\lambda_L)(\lambda_L FAC + (1 - \lambda_L)r_d) &= 50(13) = 650; \text{ and} \\ N(\lambda_H)(\lambda_H FAC + (1 - \lambda_H)r_d) &= 25(31) = 775. \end{aligned}$$

Thus, by choosing  $\lambda_H$ , the wing increases variable costs by over 19 percent.

### Customer Decisionmaking Under Two-Part Pricing Structure

Now suppose that the Air Force adopts a two-part pricing scheme. The command is charged a fixed fee,  $F_d$ , to cover the wing's portion of the depot's annual fixed costs associated with repair and replacement of this item, and the wing is charged a price that depends on the condition of the carcass that it exchanges for a serviceable item. When the unserviceable item can be repaired, the wing is charged  $r_d$ , and when it must be condemned, the wing is charged the item's FAC.



The costs faced by the Air Force have not changed, but the command and wing now anticipate costs equal to

$$F_d + N(\lambda)(\lambda FAC + (1 - \lambda)r_d),$$

which are equivalent to the Air Force's costs. Therefore, when

$$\frac{N(\lambda_L)}{N(\lambda_H)} < \frac{\lambda_H FAC + (1 - \lambda_H)r_d}{\lambda_L FAC + (1 - \lambda_L)r_d},$$

the wing will choose condemnation rate  $\lambda_L$ , which is the optimal condemnation rate from the Air Force's point of view. Similarly, when

$$\frac{N(\lambda_L)}{N(\lambda_H)} > \frac{\lambda_H FAC + (1 - \lambda_H)r_d}{\lambda_L FAC + (1 - \lambda_L)r_d},$$

the wing will choose condemnation rate  $\lambda_H$ , which is optimal from the Air Force's point of view.

Through use of a multipart price scheme that depends on the state of repair, the wing chooses to exert effort to achieve the cost-minimizing condemnation rate from the Air Force's point of view, and total costs associated with repair and replacement of this item are recovered from both the wing and the command.

### AN ITEM IN EXCESS SUPPLY

In this example, we derive the true cost imposed upon the supply system by a demand for a serviceable item that is in excess supply. Suppose that the Air Force desires to reduce its serviceable inventory of an NSN to  $k$  units because of factors such as increased efficiency in the repair shop, reduced transportation times, a reduction in the number of active aircraft, and so forth. There are currently  $m$  spares of this item in supply, with  $m > k$ . As a result of this new policy, the next  $m - k$  unserviceables exchanged for the serviceable items will not be repaired and returned to the serviceable inventory. After the inventory is drawn down, unserviceables will be repaired and returned to the inventory. (The intention is that during peacetime

the inventory will not be allowed to fall below  $k$ .) We assume that only one wing requires this NSN, and there is uncertainty about whether the wing will need a serviceable item each period.

Each time the wing draws a serviceable item from supply, it imposes a cost on the supply system by decreasing the time until the inventory of spares is depleted and repairs need to be resumed. Let  $C(n)$  denote the discounted present value of all future repair costs (over an infinite horizon) given that there are currently  $n$  remaining spares. The function is decreasing in  $n$  for  $n \geq k$  because additional spares extend the time until repairs are needed.

When  $n = k$ , the cost of drawing a serviceable item is  $r_d$ , the marginal cost of repairing one item at the depot. The discounted present value of costs when the  $k^{\text{th}}$  spare must be drawn (assuming the wing never needs more than one each period) is

$$r_d + \beta C(k).$$

$\beta$  is the discount factor  $1/(1+i)$ , where  $i$  is the per-period interest rate. When  $n = k$  and there is no demand during the period, no repair costs are incurred and the discounted present value of costs is

$$\beta C(k).$$

Letting  $\theta$  denote the probability that the wing will need a serviceable item from stock this period, the expected cost associated with having  $k$  items in stock is

$$C(k) = \theta(r_d + \beta C(k)) + (1 - \theta)\beta C(k)$$

or

$$C(k) = \theta r_d + \beta C(k),$$

which simplifies to

$$C(k) = \frac{\theta r_d}{1 - \beta}.$$

For  $n = k + 1$ , no current repair costs are incurred when a spare must be drawn, but the stock of items in the next period is diminished by 1. Therefore, the cost of drawing the  $k + 1^{st}$  item is the change in discounted present values

$$\beta(C(k) - C(k + 1)).$$

If no spare is requested this period,  $n = k + 1$  again next period. Thus, the expected cost associated with having  $k + 1$  items in stock today is

$$C(k + 1) = \theta\beta C(k) + (1 - \theta)\beta C(k + 1),$$

which can be rewritten as

$$C(k + 1) = \frac{\theta\beta C(k)}{1 - (1 - \theta)\beta}.$$

More generally, when there are  $n > k + 1$  spares, the cost of drawing a serviceable item from stock is

$$\beta(C(n - 1) - C(n)).$$

Substituting

$$\theta\beta C(n - 2) + (1 - \theta)\beta C(n - 1) \quad \text{for} \quad C(n - 1)$$

and

$$\theta\beta C(n - 1) + (1 - \theta)\beta C(n) \quad \text{for} \quad C(n)$$

yields

$$\begin{aligned} \beta(C(n - 1) - C(n)) &= \beta(\theta\beta C(n - 2) + (1 - \theta)\beta C(n - 1)) \\ &\quad - \beta(\theta\beta C(n - 1) + (1 - \theta)\beta C(n)). \end{aligned}$$

This can be rewritten as a function of  $\theta$ ,  $\beta$ , and  $r_d$  through the following simplifications:

$$C(n-1) - C(n) = \frac{\theta\beta(C(n-2) - C(n-1))}{1 - (1-\theta)\beta},$$

$$C(n-1) - C(n) = \frac{(\theta\beta)^{n-k-1}(C(k) - C(k+1))}{(1 - (1-\theta)\beta)^{n-k-1}},$$

and finally

$$C(n-1) - C(n) = \left[ \frac{(\theta\beta)^{n-k-1}}{(1 - (1-\theta)\beta)^{n-k-1}} \right] \left[ \frac{\theta r_d}{1 - (1-\theta)\beta} \right].$$

We draw on the lessons from cases 1 through 5 to derive exchange prices for the item that reflect the costs imposed upon the supply system when a wing draws a serviceable part. The appropriate exchange price charged for this item is

$$P(n) = \beta(C(n-1) - C(n)) \text{ for } n \geq k+1$$

$$P(n) = r_d \text{ for } n = k$$

where  $P(n)$  is the price charged for a serviceable item when there are  $n$  spares.

Note that  $P(n)$  is decreasing in  $n$  because  $\theta\beta/(1 - (1-\theta)\beta) < 1$ .

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